SILICON CHIP

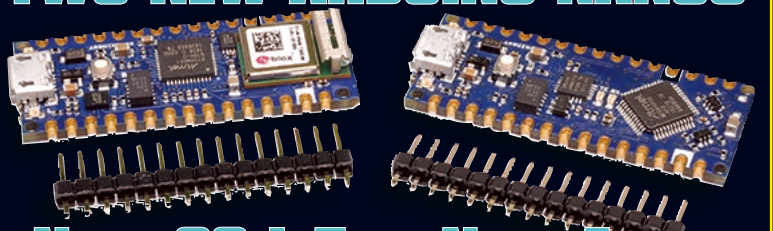
OCTOBER 2019
ISSN 1030-2662
10
9 771030 266001
$9.95* INC GST NZ $12.90 INC GST

The VERY BEST DIY Projects!

NEW BENCH SUPPLY: 45V 8A

Constant Voltage • Constant Current • With digital display

TWO NEW ARDUINO NANOS



Nano 33 IoT **Nano Every**

- More Powerful!
- More Versatile!
- And they cost less!

MORE TEST GEAR!

High-Res Audio Millivoltmeter

Precision Audio Signal Amplifier

They Called It "The Thing"

This magnificent carving – a gift from the USSR to the USA for their new Moscow embassy – also contained the world's cleverest "bug" – which went undetected for many years!

Read all about it - and more - inside!

awesome projects by

jaycar

think. possible.

On sale 24 September to 23 October, 2019

Our very own specialists are developing fun and challenging Arduino® - compatible projects for you to build every month, with special prices exclusive to Club Members.

PROJECT OF THE MONTH: Silent alarm clock

Do you need an alarm clock that doesn't wake up anyone next to you? Do you wake up, look at the time and fall asleep again? Using our new RGB shield, this silent alarm clock provides an amazing colourful display that simulates daylight to gently wake you up.

Want to know the time? Just give two loud claps and will display it out on the RGB shield.

SKILL LEVEL: Intermediate
TOOLS: Soldering Iron

SEE STEP-BY-STEP INSTRUCTIONS AT:
www.jaycar.com.au/silent-alarm-clock

WHAT YOU NEED:

1 × DuinoTECH Classic (UNO)	XC4410	**$29.95**
1 × Data Logging Shield	XC4536	**$19.95**
1 × 8x5 RGB LED Shield	XC3730	**$19.95**
1 × Microphone Sound Sensor Module	XC4438	**$7.95**

See other projects at www.jaycar.com.au/arduino

NERD PERKS BUNDLE DEAL

$39.95

SAVE 45%

KIT VALUED AT: $77.80

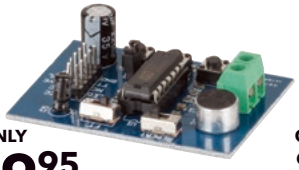
Make your project musical

Coin not included

ONLY $4.95

Mini PC mount buzzer 9-14V

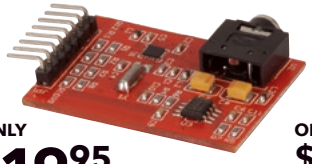
Use some traditional alarm clock tones with this mini buzzer. AB3459



ONLY $9.95

Record and playback module

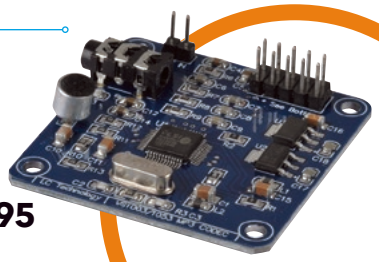
Set yourself some quick personal reminders with the record and playback module triggered by your Arduino® Silent Alarm Clock project. XC4605



ONLY $19.95

Si4703 FM tuner breakout board

Get the daily local news with a FM Tuner board added to your Silent Alarm Clock project. XC4595



ONLY $24.95

MP3 recording module

Pair this module with an SD card and Arduino® to turn on your favourite song when it's time to get up. XC4516

exclusive club offer

15% OFF

HDMI LEADS & ADAPTORS*

**See T&Cs for details*

your club. your perks!

Check your points & update details online.
Login & click "My Account"
Conditions apply. See website for T&Cs

Shop the catalogue www.jaycar.com.au 1800 022 888

Contents

Vol.32, No.10 October 2019

SILICON CHIP
www.siliconchip.com.au

Features & Reviews

12 History of Cyber Espionage and Cyber Weapons, Part 2

Last month we looked at some of the techniques used. Now we move onto a lot of the ingenious hardware they used (and still use today). Some of it can even be bought over-the-counter! – by Dr David Maddison

34 Two new Arduino Nanos: the "Every" and the "33 IoT"

We take an in-depth look at the latest offerings by Arduino . . . and we were very impressed. They're very powerful but they're low in cost – by Tim Blythman

61 Three Arduino Motor Driver Shields

If you're building anything with motors, you'll need something to drive them. Here we look at three motor driving Arduino shields – by Tim Blythman

Constructional Projects

22 45V, 8A Bench Power Supply to build

This linear design will take pride of place on your work bench. It can supply up to 45V at 8A or even more at lower current – 50V @ 2A. With current limiting and a very stable voltage it's the one you've been waiting for – by Tim Blythman

42 High resolution Audio Millivoltmeter/Voltmeter

With unbalanced (<56µV-60V RMS) and balanced (<56µV-600mV RMS) inputs and a frequency range of 5Hz-110kHz +0, -3dB and accuracy of 0.1%, it's another worthy test bench instrument. It runs off 5V DC (USB output or a 5V supply) – by Jim Rowe

76 Solving one of Home Automation's biggest beefs!

The interface between your home automation system and you is often the worst feature. Two new Arduino wallplates from Altronics, one with a touchscreen, look like going a long way to solving that problem – by Tim Blythman

91 Precision Audio Signal Amplifier

You might not need it every day – unless you do testing and calibration every day – and then you'll wonder how you got along without it! A perfect partner for above Audio Millivoltmeter – by Jim Rowe

Your Favourite Columns

70 Serviceman's Log

A shockingly cute new companion – by Dave Thompson

98 Circuit Notebook

(1) Three Norton (current feedback) amp based sinewave oscillators
(2) Amplifying audio signals using a MAX232CPE serial driver chip
(3) Multiple DS18B20 temperature sensors on a single, long wire
(4) Loudspeaker "thump" suppressor

105 Vintage Radio

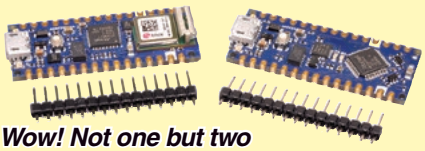
Healing M602T transistor mantel radio – by Ian Batty

Everything Else

2 Editorial Viewpoint
4 Mailbag – Your Feedback
39 Product Showcase
40 SILICON CHIP ONLINE SHOP
102 Ask SILICON CHIP
111 Market Centre
112 Advertising Index
112 Notes and Errata

They called it "The Thing" – a beautifully carved Great Seal of the USA, a gift from the Russians for the new US embassy in Moscow. But hidden inside was an incredibly clever passive "bug" and it was not discovered for many years! – Page 12.

We've been promising this for many months – and here it is! This linear Bench Supply can deliver up to 45V at a whopping 8A! – Page 22



Wow! Not one but two new Arduino Nanos: the Every and the 33 IoT. They might be cheap but they're certainly not nasty! – Page 34

A high resolution Audio Millivoltmeter is a "must have" for the serious hobbyist or service tech – Page 42

And here's another piece of test gear if you're really serious! It's a precision Audio Signal Amplifier so you know your measurements will be spot on! – Page 91

Want to get into Home Automation? These new "Inventa" wallplates from Altronics make interfacing easier – Page 76

Find us on Facebook
www.facebook.com/siliconchipmagazine

SILICON CHIP
www.siliconchip.com.au

Publisher/Editor
Nicholas Vinen

Technical Editor
John Clarke, B.E.(Elec.)

Technical Staff
Jim Rowe, B.A., B.Sc
Bao Smith, B.Sc
Tim Blythman, B.E., B.Sc

Technical Contributor
Duraid Madina, B.Sc, M.Sc, PhD

Art Director & Production Manager
Ross Tester

Reader Services
Ann Morris

Advertising Enquiries
Glyn Smith
Phone (02) 9939 3295
Mobile 0431 792 293
glyn@siliconchip.com.au

Regular Contributors
Dave Thompson
David Maddison B.App.Sc. (Hons 1), PhD, Grad.Dip.Entr.Innov.
Geoff Graham
Associate Professor Graham Parslow
Ian Batty

Cartoonist
Brendan Akhurst

Founding Editor (retired)
Leo Simpson, B.Bus., FAICD

SILICON CHIP is published 12 times a year by Silicon Chip Publications Pty Ltd. ACN 626 922 870. ABN 20 880 526 923. All material is copyright ©. No part of this publication may be reproduced without the written consent of the publisher.

Subscription rates (12 issues): $105.00 per year, post paid, in Australia. For overseas rates, see our website or email silicon@siliconchip.com.au

Editorial office:
Unit 1 (up ramp), 234 Harbord Rd, Brookvale, NSW 2100.
Postal address: PO Box 139, Collaroy Beach, NSW 2097.
Phone (02) 9939 3295.
E-mail: silicon@siliconchip.com.au

ISSN 1030-2662
* Recommended & maximum price only.

Printing and Distribution:
Spotpress
24-26 Lilian Fowler Pl, Marrickville 2204

Editorial Viewpoint

Encouraging chip developments

I'm thrilled to see that Advanced Micro Devices (AMD) are making a comeback in the desktop/notebook CPU market with their Ryzen 3000 series of processors. These have finally overtaken the latest Intel chips in some benchmarks, and offer outstanding value for money.

I was quite concerned in 2016 when they nearly went bankrupt, since without AMD, Intel would have a virtual monopoly in the CPU market, with little incentive to innovate. Recall that it was AMD who released the first 64-bit x86-compatible CPU in April 2003. Intel quickly implemented a compatible 64-bit scheme, lifting us from the looming 4GB memory access limit.

AMD has also historically helped to keep CPU prices down. Their strategy to compete has been to offer almost as much performance as Intel chips at much lower prices. They also helped to popularise multi-core computing, as their first dual-core Athlon 64 CPU was released in April 2005, a full year before Intel brought their Core 2 Duo processor series to market.

The current 'race' seems to be to see who can jam the most cores on a single chip. The current innovation is the idea of separating the chip cores themselves and the onboard I/O controller onto separate silicon dies, and bonding them together in a single package with very fast interconnects.

That brings the possibility of using multiple core dies in a single chip, which is what AMD has done with the Ryzen 9 3950X, jamming 16 cores with 32 threads into a single package with a maximum 'boost' clock of 4.7GHz. It's impressive engineering and no doubt Intel is rushing to leapfrog AMD.

On a different topic, Xilinx recently announced their Virtex VU19P, a huge new FPGA (Field Programmable Gate Array). It's built on TSMC's 16nm process and boasts nine million logic cells, more than 16GB of onboard memory and 460GB/s memory bandwidth. It's an astounding device.

This is a vast (and expensive!) chip, with a die size of around 900mm^2, capable of implementing 16 ARM Cortex A9 cores simultaneously. I'm told the logic compile/synthesis time for a design that fills the chip is around two days!

A device like this would be very handy for those designing moderately-sized CPUs or very large scale logic devices. It's a lot faster to test such a device by uploading it to an FPGA and then running tests on that, compared to software simulations. And you definitely want to test your design thoroughly before spending millions of dollars on having ASICs (Application-Specific ICs) made. So you'd need the latest cutting-edge FPGA.

In even more pioneering news, MIT researchers and Analog Devices recently succeeded in building a 32-bit processor called the RV16X-NANO using carbon nanotubes. It has around 14,000 individual transistors made from semiconducting nanotubes.

As with many other unproven new processor technologies, I am a little sceptical as to whether this will ever catch up with traditional CMOS logic in terms of performance at commercial scales. But the fact that a working chip has been made means that the technology is a lot closer to production than many other technologies, even if it runs at a rather pathetic 10kHz clock speed.

For more information, see: siliconchip.com.au/link/aauy

Nicholas Vinen

1,500,000+ PRODUCTS IN STOCK | 7.9 MILLION+ PRODUCTS ONLINE

Semiconductors
Passives
Electromechanical
Power
Circuit Protection
Automation
Connectors
Interconnect
Hyperfast
IoT
Switches
RFID
TMR Magnetic Sensors
RF Directional Couplers
Bipolar Digital Latching Sensor
Logic
Digital Omnipolar
Crystals
Augmented Reality
Earth-Friendly Display
Embedded Cellular
IO-Link
Solenoids
Proximity Sensor
Capacitive Touch
Embedded Computers
Thermocouple Interface
PIR Sensor
SPI Interface
Linear
Ultra Low-Power
Narrowband
Mesh-Networked
Virtual Reality
Keyfob
Isolators
MCUs
RF Evaluation
Dev Boards
RF Antennas
Axis Tilt
Zettabyte Era
I2C
Robotic Process Automation
Microservice Architecture
Rezence Compatible
XCVR
Immersive Experience
Artificial Intelligence
Internet of Things
Na-TECC
3D Alteration
Quantum Computing
Shunt Sense
Touchless
Smart Home Technology
5G Mobile
Energy Harvesting
MotorData Acquisition

YOU INNOVATE!

Infrared Thermopile
Triboelectric
Magnetic Position
Gesture Control
Interconnect
Rectenna
Connected Cloud
Decoupled Network
Hybrid Envelope-Tracking Signal
Re-Entrant Leveraged Design
Embedded Logic
TEGs
Passives
Logic Eco-System
Third-Order Sensor
Clock/Timing
Memory
Filters
SoC
Thermal Management
Class-G Amplifier
Decimated Power-Efficiency
Microwave
Bluetooth
Remote Control
FPGA
DDS
Batteries
Betavoltaics
MiWi Transceiver
Nanogenerators
AMR
Recycling Radiowaves
Ask Receiver
Transformers
Solar
Sensor
2-Way Remote
Simplex Transmission
ADC
Potentiometers
Interface
NFC
Frequency Synthesizers
Oscillators
Low Energy
PMIC
Relays
WPC-Certified
Smart Devices
Capacitors
Electromechanical
Optoisolators
ZigBee
Semiconductors
EMI
Tools
Hardware
Cable

We Make It Easy.

AUSTRALIA
DIGIKEY.COM.AU
1800 285 719

NEW ZEALAND
DIGIKEY.CO.NZ
800 449 837

Digi-Key® ELECTRONICS

800+ INDUSTRY-LEADING SUPPLIERS | 100% AUTHORIZED DISTRIBUTOR

*__Australia:__ A shipping charge of $24.00 AUD will be billed on all orders of less than $60.00 AUD. A shipping charge of $20.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS, Federal Express, or DHL for delivery within 3-4 days (dependent on final destination). No handling fees. All prices are in Australian dollar or United States dollar. __New Zealand:__ A shipping charge of $26.00 (NZD) will be billed on all orders of less than $66.00 (NZD). A shipping charge of $20.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS for delivery within 3-4 days (dependent on final destination). All prices are in New Zealand dollar or United States dollar. Digi-Key is an authorized distributor for all supplier partners. New product added daily. Digi-Key and Digi-Key Electronics are registered trademarks of Digi-Key Electronics in the U.S. and other countries. © 2019 Digi-Key Electronics, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA

ECIA MEMBER
Supporting The Authorized Channel

Letters and emails should contain complete name, address and daytime phone number. Letters to the Editor are submitted on the condition that Silicon Chip Publications Pty Ltd may edit and has the right to reproduce in electronic form and communicate these letters. This also applies to submissions to "Ask SILICON CHIP", "Circuit Notebook" and "Serviceman".

Tingles should not be ignored!

Regarding the letter from Howard Maddaford on page 10 of the August 2019 issue (Mailbag), titled "Household Earthing can be dangerously inadequate", the letter should be sounding alarm bells.

It would appear Mr Maddaford has had an electrician inspect the installation. If the installation Earthing system, MEN and Neutral connections have been tested and are sound, and the fault still exists, then the electrician should seek further assistance.

To tell any client that receiving tingles from taps etc is "OK" beggars belief. A dangerous Neutral fault may exist upstream, in the utility's supply network.

Although an extreme case, in March 2018, an 11-year-old girl in Perth WA received a near-fatal electric shock when turning off a garden tap. As a result, she received severe brain injuries. An open-circuit Neutral was suspected as the culprit.

Now that you have published the letter, you should inform Mr Maddaford to take further action. He should either contact the utility supplier Western Power or the West Australian Government Department of Energy Safety.

I expect that neither will conclude receiving tingles/electric shocks from taps and plumbing pipes is acceptable and will follow up with a prompt investigation.

The reply from Nicholas was also a little disappointing. He admits that his Earth stake is buried in concrete and probably not very effective (probably quite correct). The location of this Earth stake would likely be non-compliant.

It would be wise to get your Earth stake relocated to an appropriate location. As was described in previous issues of SILICON CHIP, due to our MEN system, if the supply Neutral is broken for any reason, your Earthing system can be at mains potential. Your Earth stake is the last line of defence.

Allan Doust,
Erskine, WA.

Response: we agree that nobody should be getting 'tingles', except perhaps from double-insulated equipment like laptop computers and disc players. These can sometimes deliver small shocks due to their power supply design, which we consider unacceptable, but it isn't hazardous; just annoying!

Safe Earthing relies on a good Neutral connection

In the letter "Household Earthing can be dangerously inadequate" published in the August edition, both the writer and editor imply that with the MEN system, a consumer's Earth resistance must be a low value to afford safety.

That isn't really the case because safe operation of the MEN system is not dependent on fault current being conducted through the ground; rather, the Neutral conductor in the street provides a low impedance return path to the supply authority's distribution substation, courtesy of the MEN link which bonds Earth wires to the Neutral at consumers' main switchboards.

Although Section 5 of AS/NZS 3000 states that a consumer's Earth electrode should be installed in ground that won't dry out, there is no mandated resistance to Earth; it only stipulates that a vertical rod electrode be at least 1.2m long.

A commonly used formula indicates that Earth resistance of a 1.2m long, 12mm diameter electrode in average soil of 100Ωm resistivity would be 70Ω, hardly low enough to allow sufficient fault current to trip a circuit breaker. And although the water main can provide a very low resistance to Earth, that can't be relied on these days due to the use of plastic piping.

The Neutral of the MEN distribution system is Earthed at multiple points to deal with an inherent weakness of that system.

When load currents in the three phases of the street mains become unbalanced, as often occurs due to changing residential loads, residual current flows in the street Neutral, causing it to rise above Earth.

This is counteracted by Earthing the Neutral at many points – at every second street pole of an overhead system and at all connected residences.

So a consumer's Earth electrode is not required for promotion of fault current but as a contribution, along with all the other points of Neutral Earthing, to keep the Neutral-Earth voltage low.

Russell Howson,
Bronte, NSW.

Response: you are absolutely right, according to the requirements of AS/NZS 3000 (Wiring Rules). And as you say, this system is safe, providing the premises has a good connection back to the Neutral in the street.

But the question is whether this guarantees safety should the Neutral link fail. As you say, the local Earth connection impedance is typically too high to provide protection in that case. We know that the Neutral link can fail on occasion, due to corrosion or other factors.

One would hope that the RCDs, now required on virtually all circuits in new installations, would still operate and provide protection from shocks even without the Neutral link and even with a relatively high-impedance Earth connection. But we aren't sure if that is the case. It may depend on the exact nature of the RCDs fitted, be they electro-mechanical or electronic.

This leaves us with a situation where residents of older buildings without full RCD protection are at significant risk if the Neutral link should fail.

One Development Environment—All Solutions

MPLAB® Ecosystem is Comprehensive, Powerful and Simple

The MPLAB ecosystem now provides comprehensive product support and powerful debug tools that can increase your confidence in your design. Key features in MPLAB X Integrated Development Environment (IDE) include I/O View to display and modify pin states on the fly and Data Visualizer to stream real-time data and provide terminal windows all within a single tool. MPLAB X IDE also offers automatic hardware detection to provide register definitions and links to product data sheets and applicable software libraries to make your development even easier.

What more could you ask for? How about cost- and time-conscious tools? The MPLAB ICD 4, MPLAB PICkit™ 4 Programmer and MPLAB Snap offer fast debugging at multiple price points. And our powerful, free tools such as MPLAB XC compilers, MPLAB Code Configurator, MPLAB Harmony, product simulators and software libraries offer quick development at minimal cost.

The MPLAB ecosystem has never offered more flexibility, freedom and capabilities for all our microcontroller (MCU), microprocessor (MPU) and Digital Signal Controller (DSC) products.

Highlights

- Freedom to use any Microchip MCU, MPU or DSC with one toolset
- Full workstation flexibility with support for Windows®, Linux® or macOS® operating systems
- New features to speed up design process
- Full range of debuggers for all price points and capabilities
- Automatic demonstration board identification to easily get started

MPLAB® X IDE

Contact Information
Microchip Technology Australia
Email: aust_nz.inquiry@microchip.com
Phone: +61 (2) 9868-6733

microchip.com/MPLABecosystem

MICROCHIP

The Microchip name and logo, the Microchip logo and MPLAB are registered trademarks and PICkit is a trademark of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners.
© 2019 Microchip Technology Inc. All rights reserved.

OCEAN CONTROLS
Helping to put you in Control

LogBox Connect 3G
The LogBox 3G is an IoT device with integrated data logger and 3G / 2G connectivity. Free access to Novus Cloud for storage and access to data
SKU: NOD-011
Price: $699.95 ea + GST

Temperature and Humidity Sensor
Ideal for building automation applications the RHT-WM is an accurate wall mount temperature and humidity sensor with 4 to 20 mA outputs and is loop powered. Adjustment of output ranges can be made with TxConfig PC interface.
SKU: RHT-003
Price: $209.00 ea + GST

DC Earth Fault Relay
A Din rail mounted current sensing relay dedicated for DC earth fault monitoring, such as insulation deterioration on a DC system. The unit is supplied complete with a dedicated DC Earth Fault CT.
SKU: NTR-290
Price: $245.00 ea + GST

Split core current transducer
Split core hall effect AC current transducer presents a 4 to 20 mA DC signal representing the AC current flowing through a primary conductor. 0 to 100 A primary AC current range.
SKU: WES-076
Price: $109.00 ea + GST

Programmable Logic Relay
The TECO SG2 Series PLR V.3 is 24VDC Powered, has 6 DC Inputs, 2 Analog Inputs, 4 Relay Outputs, Keypad / Display, Expandable (Max. 34) I/O.
SKU: TEC-005
Price: $149.95 ea + GST

3 Digit Large Display
Large three digit universal process indicator accepts 4 to 20mA signal with configurable engineering units. 10cm High digits. 24V DC Powered.
SKU: DBI-020
Price: $449.00 ea + GST

Raw & Waste Water Level Sensor
2 wire 4 to 20 mA liquid level sensor 0-3m. Suitable for raw and waste water. Supplied with 10m cable.
SKU: IBP-104
Price: $369.00 ea +GST

For Wholesale prices
Contact Ocean Controls
Ph: (03) 9708 2390
oceancontrols.com.au
Prices are subjected to change without notice.

One also has to wonder how it's possible to drive the Earth stake into soil which will remain moist in dry areas of Australia which are prone to multi-year droughts. There's also the question of whether Earth stakes passing through concrete slabs (which is fairly common) are compliant with the standard, since the concrete may prevent water from reaching the soil below.

Earthing via pipes promotes corrosion

I feel I must strongly object to the remedy suggested by your editor in response to Howard Maddaford's letter concerning his perceived inadequate household Earthing.

There is an important reason for the length of plastic pipe inserted into his water main. The plastic is there to isolate his plumbing to prevent copper corrosion of pipes internal to his home. This has been mentioned as a solution to copper corrosion in your magazine in the past.

I and most of my family and friends, with homes built from the '70s with copper pipe, have experienced copper corrosion. This necessitates the complete replacement of their copper plumbing, often with the new flexible plastic alternative. It has also been linked to premature failure of hot water services. This is obviously expensive!

Current regulations mandate that a separate Earth stake be provided to Earth household wiring. That is, the household Earth must be completely isolated from plumbing, particularly as there is no guarantee today of the conductivity of internal plumbing.

Any new Earth wiring in the house must also be insulated so as not to contact plumbing. Any new plumbing or electrical work requires this and Mr Maddaford's electrician and plumber should have been aware of this.

As to Earthing stakes, they are available in various lengths with regulations stipulating the length for Earth condition type.

Bob Backway
Belgrave Heights, Vic.

Response: we can't find anything in AS/NZS 3000 which prohibits connections between the household Earth and plumbing. It is certainly not required but nor does it appear to be prohibited.

It would be a good idea for any metal plumbing to be Earthed separately to the electrical system, to prevent a hazard should it somehow come in contact with a live Mains conductor. We're not sure whether that would affect corrosion resistance.

While it makes sense that current flowing through pipes can promote corrosion, surely this would be limited to the area near where they meet the ground, and not within the dwelling, where no current should be flowing.

More comments on safe Earthing practices

In response to Howard Maddaford's letter in your August issue, I believe some misunderstandings should be rectified.

There's no requirement in the wiring rules for your Earth stake to be "effective". It isn't your Earth stake that keeps the metalwork in your house at ground potential.

It wasn't a faulty Earth stake that was the cause of the accident at Beldon in Western Australia. It's not a faulty Earth stake that causes plumbers to receive shocks when they cut pipes without bridging them.

What keeps your house at ground potential is a short piece of thick wire in your switchboard that bridges your main supply return path with:

- the Earth wires for each circuit
- any connections to your pipework
- your Earth stake
- your frame (if it's metal)
- your slab (if applicable)
- your switchboard enclosure

What does cause shocks is a faulty return path, for example, a break in the Neutral conductor supplying your house.

If you're getting tingles, it means that something you're touching is not properly Earthed and is close to a power cable. Instead of asking your electrician to check your Earth stake, you should ask him to use a high-impedance voltmeter to test the voltage between whatever you are getting tingles from (your feet?) and a known Earth.

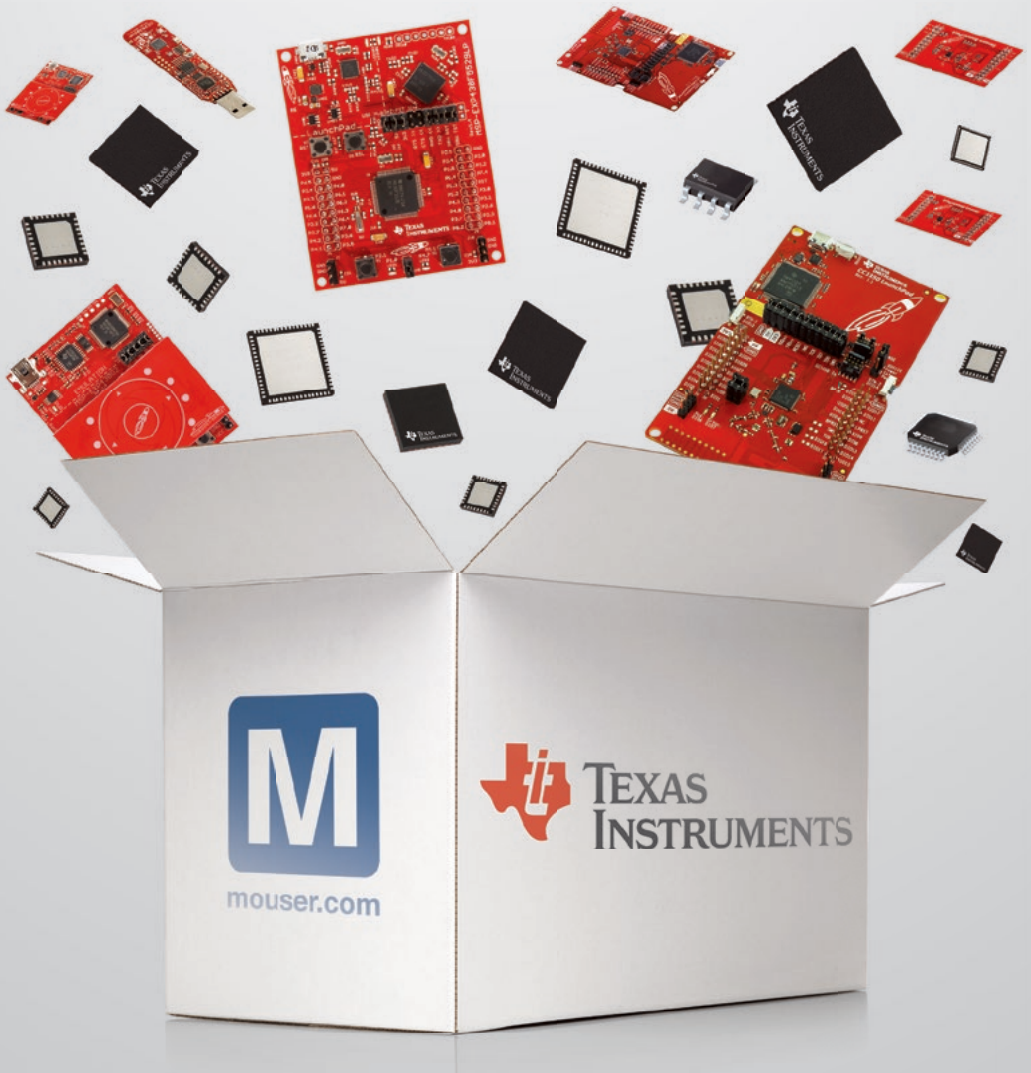
Tingles should not be ignored. If the insulation in that power cable were to fail, there would be no return path and your circuit protection would not operate, creating a very dangerous situation.

Paul Smith,
King Creek, NSW.

"Cable PI" is not foolproof

On page 8 of the April 2019 issue, in a comment on a letter from Paul

Stocking the Largest Portfolio of TI Products



46,000+ TI Products **4,000+ TI Dev Tools**

Mouser Electronics – your authorized TI distributor stocking more products for your next design.
au.mouser.com/manufacturer/texas-instruments/

MOUSER ELECTRONICS

australia@mouser.com

Smith, reference is made to the Tasmanian Cable PI.

This device is quite heavily touted in Tasmania as an electrical safety device. How this product can possibly work is beyond my ken.

I recently was asked to look at a washing machine that gave out 'tingles'. When I confirmed the appliance was OK and suggested that the house Earth wiring might be at fault, the customer stated that the house was electrically safe because the "Cable PI said so".

My point is that this device leads house-holders to believe all is well when it may not be. It might be a worthwhile exercise for SILICON CHIP to run their eye over the Cable PI.

Regards and thanks for an excellent magazine.

Don Selby,
Tasmania.

Response: we agree that a simple device that plugs into a mains socket won't necessarily pick up all hazardous electrical faults. It appears that the Cable PI only has connections to the Active and Neutral, and is only capable of detecting high or low mains voltage. Without an Earth connection, it has no chance of detecting many of the possible faults that may occur. Of course, it cannot detect faults isolated in other circuits.

This is based on: www.youtube.com/watch?v=dvJbNqfYxeU The video hints that there may have been a fault with some units, but even the one shown in the official Tas Networks video has no Earth pin.

Remarks on valve filament voltages

In Graham Parslow's Vintage Radio article on the Kriesler model 31-2 which you published in the September 2019 issue, on page 117, he states:

"Although the 1-series of valves nominally work with 1V across their filament, they need at least 1.5V for good performance."

I disagree with this statement and think that it is likely to lead to confusion. Typical 1-series valves specify a filament voltage of either 1.4V or 2.0V. None of them have a specification as low as 1V. (anonymous, via email)

Graham Parslow responds: *This assertion is drawn from my own repeated experience on the bench.*

Portable radios show a fairly linear decrease in output as the filament voltage is reduced to 1V. Radio manufacturers specify 1.5V be connected because that is the default voltage of a fresh carbon-zinc battery. Valve manufacturers issue 1.4V as the lowest specified voltage for most of these valves, but that doesn't mean that they won't work at all at 1V.

Ian Batty adds: *I have personally tested portables kitted out with B7G miniatures designated 1R5, 1T4, 1S5, 1S4 etc. While they are specified for a filament voltage of 1.4V, I have been able to lower the filament supply to 1.0V and still have the sets work, albeit with reduced sensitivity and output.*

Perhaps Graham could have phrased that sentence a little better, but I do not think that it is wrong as such. In any case, as Albert Einstein said, the only sure way to avoid making mistakes is to have no new ideas.

While we're on the subject, it may be worth explaining valve numbering schemes. The earliest Radio Manufacturer Association issues simply went up in numerical order, for example: 10, 11, 12, 15, 27, 43, 55 etc. There was no indication of cathode type (filament or heater) and no indication of voltage.

Running out of type numbers (and probably aiming for some useful coding), the RMA chose the code NXN, with the first N as cathode voltage, X as a distinguishing letter, and the second N as the number of active electrodes.

Thus we got the 2A3, a 2.5V, three-electrode type (triode). And "2" was applied to 2.5V AC-heated valves, using either an indirectly-heated cathode, or designed with a high-mass filament that would eliminate the hum usually caused by heating a filament with AC. Some of the original "number code" types were re-issued, such as 2A7, 2B7 etc.

But car radio types would most easily operate at the nominal voltage of a 6V battery, so many of the original "number series" were re-issued in that form, such as the 6A7 re-issue of the 2A7.

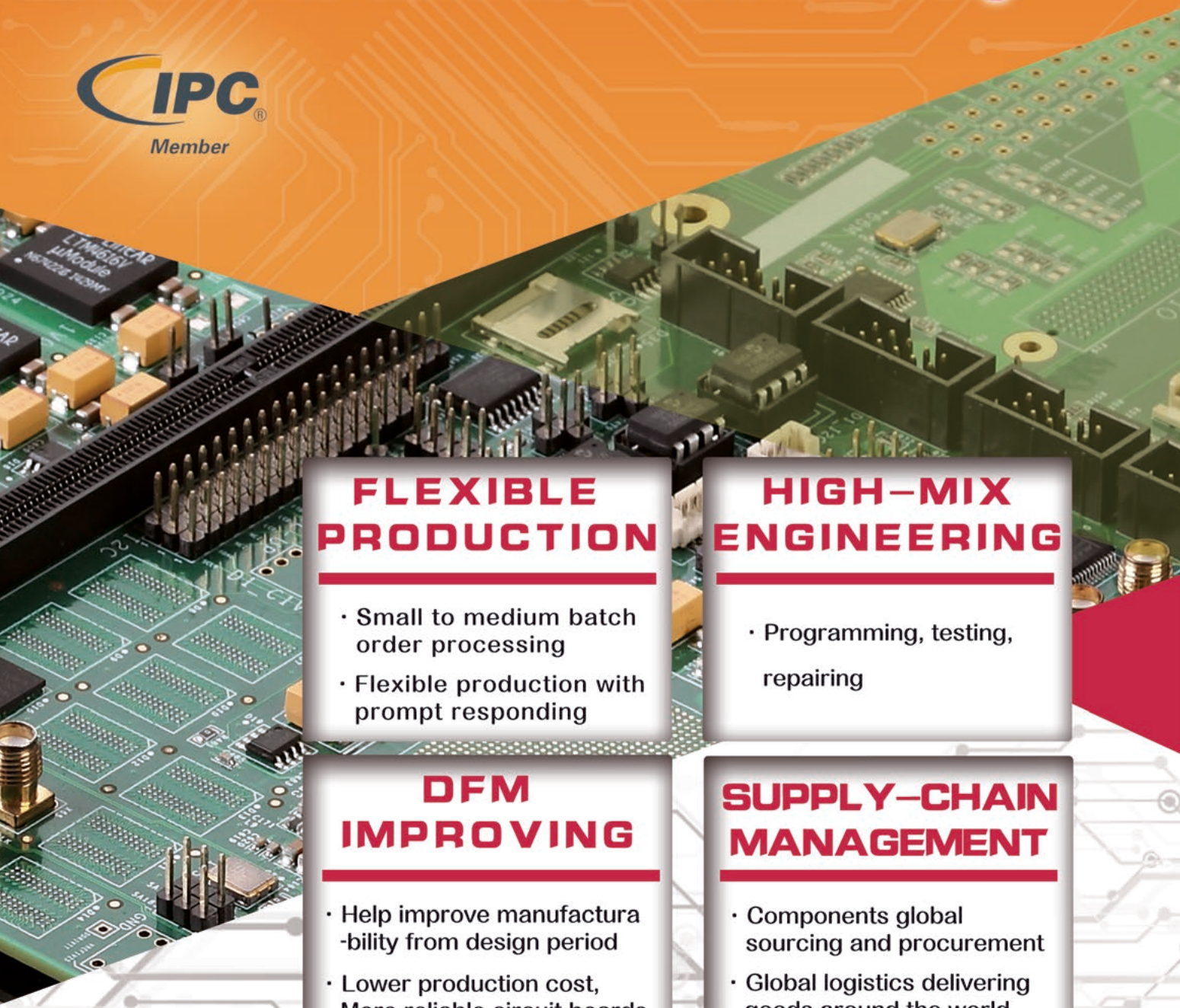
Valves for portable sets running from a single 2V accumulator caused a problem, though. Naming them 2XN would lead to confusion. Was a "2C7" pentagrid a 2.5V valve? If so, it was not going to work too well with a 2V accumulator supply. So these were issued as 1A7. That made it evident that it was not a 2.5V type, so it had to be, once you got used to the nomenclature, a 2V battery type.

EMS Since 1999

LEACH

Reliable partner for electronic contract manufacturing

IPC Member



FLEXIBLE PRODUCTION

- Small to medium batch order processing
- Flexible production with prompt responding

HIGH-MIX ENGINEERING

- Programming, testing, repairing

DFM IMPROVING

- Help improve manufactura -bility from design period
- Lower production cost, More reliable circuit boards

SUPPLY-CHAIN MANAGEMENT

- Components global sourcing and procurement
- Global logistics delivering goods around the world

LEACH (HK) Co., Ltd
LEACH (SZ) Co., Ltd
Electronic Contract Manufacturing Turnkey Solution
info@leach-pcba.com
www.leach-pcba.com

As for the B7G all-glass types, with 1.5V filaments, the only realistic option was to name then 1XN, such as the 1R5, 1T4 etc.

Perhaps this is a bit confusing, but in reality, the entire RMA/RETMA naming scheme is a bit of a mess. Why is a duo-diode (four-element valve) named 6H6? Why is a pentode (five elements) named 6AC7/6SH7/6J7? And why is the 6A7 a pentagrid; surely, if the pentodes have two magical "extra" electrodes, the pentagrid should be a 6A9!

Fluidics in nature

Dr David Maddison's article in the August 2019 issue on Fluid Logic and Fluidics mentioned a 1960 article on the subject. I recall reading that article well, because a few years before, I had seen an example of 'fluidics' on a relatively large scale in Manilla NSW, the town where I was born.

The Namoi river flows around part of the town, and there is a point where the Manilla river enters it at an acute angle, on the outside of the curve. If both rivers are high at the same time, the Manilla River (the lesser stream) can effectively 'cut off' the Namoi, leading to flooding in the town.

I suggest this is an excellent example of fluidics in action, courtesy of Mother Nature.

Thank you for an always stimulating magazine.

Bruce Bowman,
Canberra ACT.

Appreciative of Silicon Chip shortlinks

I'd like to say a big "thank you" to the person at Silicon Chip who came up with the idea of the hot links you include in most articles. For far too long my little fat fingers have managed to enter a wrong website address – especially one with lots of letter and numbers – and my browser comes back with the dreaded "404" message. It's so much easier with the hot link.

Edison Zhang,
Chippendale, NSW.

Glad you like them! It was actually due to a reader sending us an email with the exact same worries back in 2017 that got us to change to using shortlinks. We now convert most URLs to a shortlink (eg, siliconchip.com.au/link/abcd). By the way, in the online version of Silicon Chip it's even easier; just click on the hotlink and you'll be taken to the right page.

Touchscreen backlight control variations

I recently completed the Touchscreen Altimeter (December 2017; **siliconchip.com.au/Article/10898**) with parts that I bought from your online shop, including the Micromite V2 BackPack kit which came with the touchscreen. I thought I would let you know about a few minor problems I ran into building it, which I was able to resolve.

Firstly, the socket supplied for the Microbridge was a 16-pin DIL type, but it uses a 14-pin IC. Secondly, the 100Ω backlight brightness control pot specified in the article (not supplied in the kit) does not adjust the brightness. I found that I had to use a 100kΩ pot. Perhaps the newer touchscreens have a different specification?

Finally, the screws for attaching the laser-cut lid panel are not long enough to grip. I drilled and tapped the UB3 bosses and used machine screws.

Peter Bennett,
Beacon Hill, NSW

Response: Thanks for letting us know about the problems you ran into.

One of our suppliers sent us a mixed pack of 14-pin & 16-pin sockets when we ordered the 14-pin types. We tried to separate them but must have missed some. Sorry about that.

We find that the screws supplied with Jaycar UB3 Jiffy boxes are just long enough to go through the 3mm panels. But boxes from other suppliers come with shorter screws that may not do the job.

*We redesigned the lid for the V3 BackPack (August 2019; **siliconchip.com.au/Article/11764**) so that it fits inside the box, rather than over it. That solves this problem at the expense of slightly less room inside the box.*

You may be right that the touchscreens we're receiving now could be different from those we got in the past, even though we are ordering the same parts from the same supplier.

It seems that the backlight control pin may no longer directly drive the backlight cathode, but instead is a control input to an onboard backlight LED switching transistor.

That would explain why you had to change the backlight control potentiometer value so radically. We think that the 3.5-inch touchscreens used in the V3 BackPack may use a similar scheme. The good news is that the PWM backlight control circuitry seems to work the same regardless.

We'll look out for this variation in future. Your solution of using a higher-value potentiometer may well be the best one, for those who require manual backlight control (eg, when a project uses the backlight PWM pin for another purpose).

Carnarvon's role in the moon landings

I had a quick read of the latest issue of Silicon Chip which arrived today. Your bumper issue reminds me of the times when *Electronics Australia* occasionally would go wild with larger issues.

I wish to add to Alan Hughes' comment on Carnarvon being used for telemetry (Mailbag, September 2019, page 8). The most important role of the station at Carnarvon was to provide TV coverage of the moon landing to those of us living in WA at the time.

If I remember correctly, a fair bit of time and effort was expended to get us the pictures. We were quite isolated over there in the west then.

There was also a NASA ground station at Cooby Creek, north of Toowoomba, which played a role in the landing too. See: **http://siliconchip.com.au/link/aau6**

Brian Playne,
Toowoomba, Qld.

Making an inverter isolator is tough

The High Current Solid State 12V Battery Isolator by Bruce Boardman in the July 2019 issue (**siliconchip.com.au/Article/11699**) is an interesting project and the seed for other potential projects.

I have been testing some "high current" solid-state relays, but I have experienced a 100% failure for the task of isolating a 24V, 2.5kW Inverter. The problem is the initial surge current due to the large input capacitance most inverters contain.

Initial current limiting is needed to create a soft-start

mode, or I will have to find an extremely rugged solid-state switch. A challenge for you, Bruce!

Alan Bothe,
Manly, Queensland.

Response: you could consider combining Bruce's Isolator or a solid-state relay with something akin to our Soft Starter (April 2012; siliconchip.com.au/Article/705).

While that was designed for mains appliances, the principle would be much the same. You could switch in a high-power resistor using a smaller relay initially, to charge the caps, then short out both with a larger relay a few hundred milliseconds later.

Are mains projects being avoided?

Back in your Editorial Viewpoint in April 2019, you mentioned that you had a letter from the NSW Fair Trading regarding electrical safety.

As an Electrical Engineer, I have noticed over the years that there has been a tightening of regulations. For example, in South Australia, when I first graduated in 1982, my boss (an Electrical Engineer) had to sit a 'wiring rules' course to get his Electrical Contracting License.

A few years later, when I enquired, I could only get a restricted B-class license for commissioning and working on my own home. A short time later, I had to sit a four-year apprenticeship!

I am based in SA, but at times, I work on projects that are installed in Queensland. I need a RPEQ (Registered Professional Engineer of Queensland) certification to design, but cannot install, or even 'commission' these systems.

I have noted recently that the subject has been rather quiet in Silicon Chip and also there have been few mains-powered projects published of late. Is this intentional? Have the 'nannies' won? Has Silicon Chip been forced into ELV (extra low voltage) only?

I would be disappointed you are not allowed to publish projects that work at LV; how else will people learn?

Employing Electrical Engineers these days is a problem as many do not have a hobby background. When I interview, one of my first questions for a new graduate is: "see that electrical socket on the wall, what voltage would you expect?"

The purpose of this question is two-fold; one, to test knowledge; and two, to test curiosity about things electrical. Many graduates struggle with this basic question. I see this getting worse for various reasons: cheap imports, non-repairable equipment, easy to get answers from Google, lack of hobbies in this area etc

Thank you for the Silicon Chip magazine, and I hope it survives many more years, complete with LV projects.

Lindsay Freund,
Para Vista, SA.

Response: the recent dearth of mains-based projects is not intentional. John Clarke, our technical editor, says that publishing such projects is both legal and safe so long as our designs and instructions comply with the relevant safety standards.

We do have a mains-powered project in this issue, specifically, the Bench Supply starting on page 22. This is a relatively simple project, and safe for beginners as long as they follow the instructions carefully.

We don't publish quite as many mains-based projects as we used to, mainly due to changes in the sort of designs that people are interested in these days. SC

LITHIUM ION AND LITHIUM PHOSPHATE BATTERIES

Premier BATTERIES custom manufacture Li-ion and Lithium Iron Phosphate batteries for all your applications. Battery management (BMS) is fitted to all batteries. Lithium Iron Phosphate lasts up to 7 times longer than sealed lead acid and can be deep cycled without loss of capacity. It can be fast charged and has good performance in hot environments. It is also less than half the weight of lead acid batteries
Call or email your requirements for a quote

SEGWAY & E-BIKE BATTERIES

Premier BATTERIES can completely recell your Segway or E-Bike battery with new high quality cells, often giving it higher capacity and run time.
New Battery Management Systems can be fitted if required for all models – 500W, 1000W and 2000W.
Contact Premier Batteries to find out more:
info@premierbatteries.com.au

Premier BATTERIES
Custom Manufacturer of Battery Packs
Made to your specifications

Unit 9, 15 Childs Rd, Chipping Norton NSW 2170
Tel: 02 9755 1845
www.premierbatteries.com.au
email: info@premierbatteries.com.au

A BRIEF HISTORY OF CYBER ESPIONAGE AND CYBER WEAPONS

Part 2 – electronic devices for spying and surveillance

by Dr David Maddison

Last month, we described many 'side-channel attacks' which can take advantage of the vulnerabilities in electronic devices (eg, unwanted electromagnetic, visible or acoustic emissions). These can be used by third parties to extract information that they are not supposed to have access to.

We also had a section describing scenarios (real or theoretical) where hardware can or has been modified to make it easier to 'hack' and extract secret information.

This month, we'll cover the remaining electronic espionage techniques, primarily methods for eavesdropping, secretly recording video or extracting information from secure systems. Again, we will start with the earliest known techniques, although many of those described below are general techniques with their use spanning many decades.

ELECTRONIC BUGGING AND SPYING TECHNIQUES

Interception of telegraph communications

Possibly the earliest use of military eavesdropping is from 1862. During the US Civil War, President Abraham Lincoln agreed to a request from his Secretary of War, Edwin M. Stanton, to allow rerouting of telegraph lines through his office.

This let him intercept vast amounts of personal, journalistic and government information. The telegraph system back then was a bit like the internet today.

Léon Theremin's infrared microphone

Russian Lev Termen, (or Léon Theremin as he was known in the west) invented the precursor to the laser microphone some time between 1938 and 1947 (see Fig.20).

His device used an infrared beam and was called the Buran. It was capable of listening to conversations at a much greater distance than usual.

He invented it for the NKVD (KGB) after being removed from a labour camp for counter-revolutionaries and was forced to work for them in a secret laboratory. He also invented "The Thing", a microwave microphone which was first used in 1945.

Theremin's "The Thing" (US Embassy, Moscow)

"The Thing" was an ingenious invention by Léon

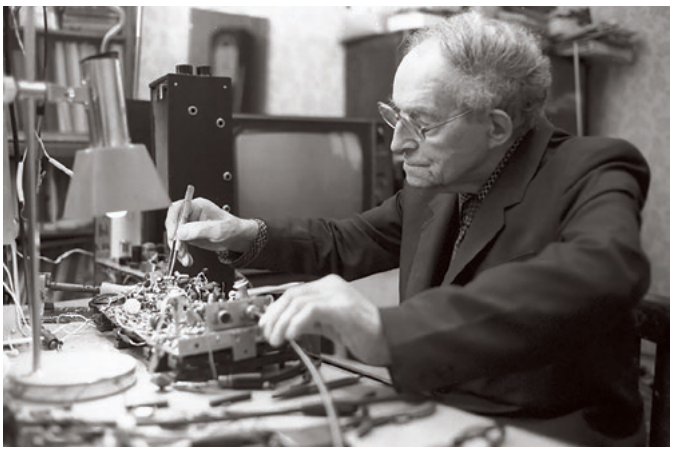


Fig.20: Léon Theremin (1896-1993) at work on one of his electronic devices. See Silicon Chip, January 2018 (siliconchip.com.au/Article/10931) for details on the musical instrument he invented, also using radio principles.

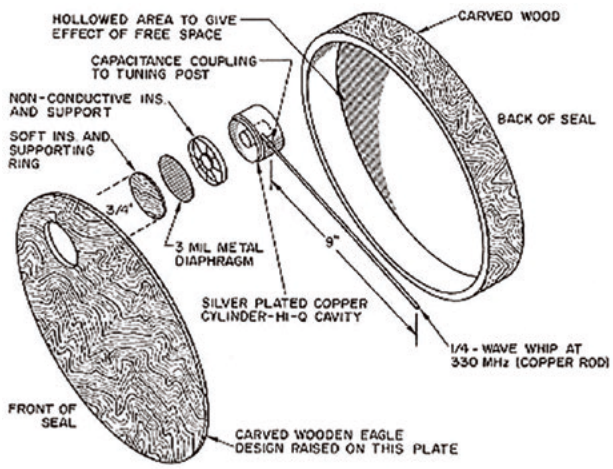

HOLLOWED AREA TO GIVE EFFECT OF FREE SPACE
CAPACITANCE COUPLING TO TUNING POST
NON-CONDUCTIVE INS. AND SUPPORT
SOFT INS. AND SUPPORTING RING
3/4"
3 MIL METAL DIAPHRAGM
9"
SILVER PLATED COPPER CYLINDER-HI-Q CAVITY
CARVED WOOD
BACK OF SEAL
1/4 - WAVE WHIP AT 330 MHz (COPPER ROD)
FRONT OF SEAL
CARVED WOODEN EAGLE DESIGN RAISED ON THIS PLATE

Fig.21: an exploded diagram showing how the bug in "The Thing" worked. It was hidden inside the Great Seal.

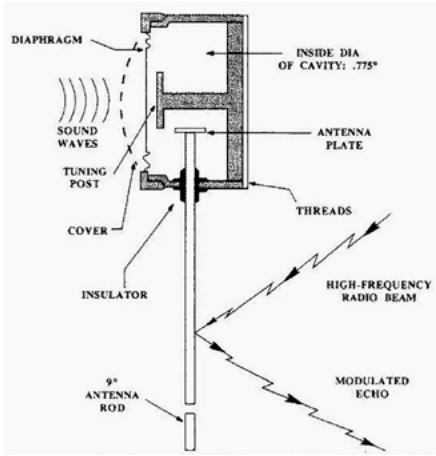


Fig.22: a cross-section of "The Thing" from the book "CIA Special Weapons & Equipment: Spy Devices of the Cold War".

Fig.23 (right): one of the most famous (infamous?) bugs ever made: Leon Theremin's "The Thing", a gift from the Soviet Union to the United States for their embassy in Moscow. The intricate US Great Seal actually concealed a listening device and was in use from 1945 until its discovery in 1952. This museum replica version can be opened to reveal the bug inside.

Theremin; a bugging device found in the US Embassy in Moscow. It was a gift from the Soviets to the USA in the form of a carved timber Great Seal of the United States.

Such was the genius of Theremin, it was in operation from 1945 until it was accidentally discovered in 1952. A passive device, it required no power to operate (see Figs.21-23).

It was a passive cavity resonator that obtained its power from outside via illumination with microwaves at 330MHz.

There were no electronic components. The working parts comprised a resonating metal membrane, a mushroom-shaped disc against which the resonating membrane was capacitively coupled, a silver-plated high-Q (high gain) cavity, a tuning device, and an antenna.

In essence, audio caused the membrane to move as in a standard microphone, and this modulated the radio waves that were illuminating the device. Specific details as to how the device worked can be found at: **siliconchip.com.au/link/aass**

In 1951, a British radio operator monitoring the Soviet Air Force from the British Embassy in Moscow heard the voice of the British Air Attaché, but could not find the bug. In 1952, a US radio operator picked up a conversation that appeared to come from the US Embassy and then the bug was discovered.

The CIA and FBI initially had no idea how the bug worked and it took British Marconi employee Peter Wright to

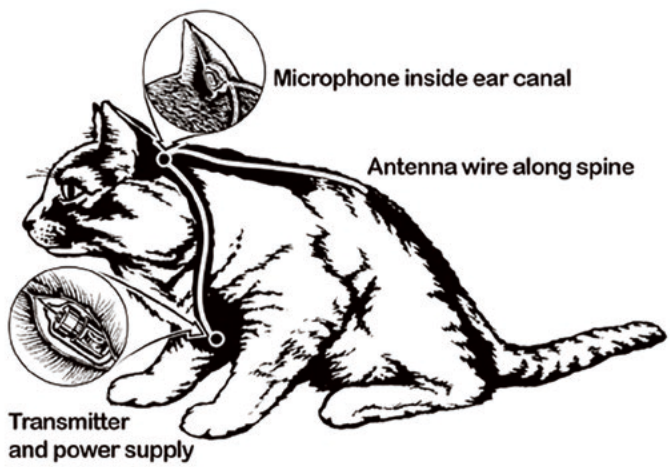


Fig.24: the CIA's "Acoustic Kitty", showing the location of the implanted electronics. The program was not a success.

Fig.25: the CIA Insectothopter from the 1970s, as displayed in the CIA museum. It was never put into service but was a remarkable achievement.

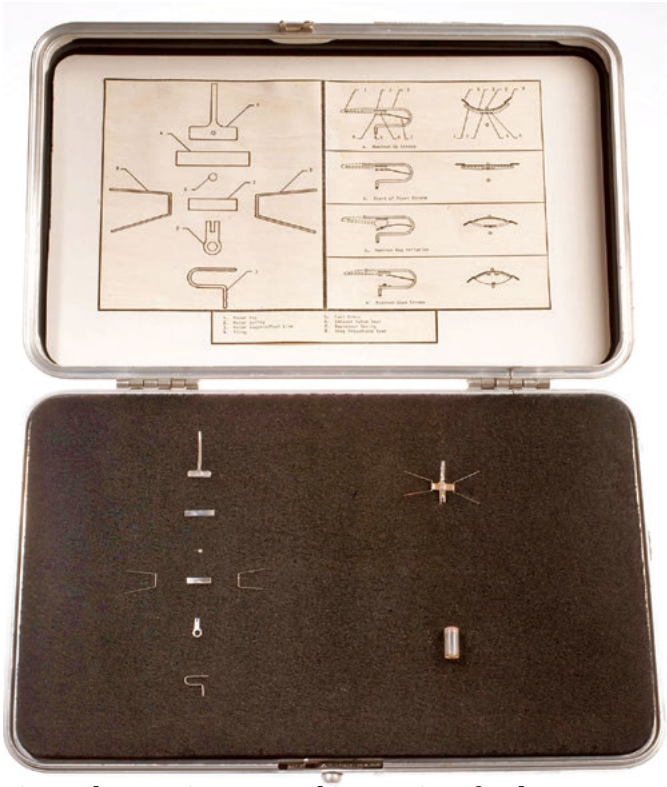


Fig.26: the carrying case and instructions for the CIA Insectothopter.

figure it out. He spent many hours of his own time to work it out, as recounted in the book "Spycatcher". See the video titled *"UN Spy Debate, Reds 'Bugged' American Embassy 1960/5/27"* at: **siliconchip.com.au/link/aast**

Animals with electronic bugs

In the early 1960s, the US CIA spent an estimated US$10-$20 million on the "Acoustic Kitty". This was a cat that had been surgically implanted with a transmitting device. The idea was for the cat to go close to its desired target (Soviets) and transmit their conversations (Fig.24).

The program was not a success, as the cat would not behave as required, especially when hungry. The cat in question had the equipment removed and went on to live a long and happy life. The program was cancelled in 1967 and disclosed in 2001.

Covert connection to undersea cables

In a famous incident in the 1970s, the USA tapped into a Soviet military undersea cable. The nuclear-powered listening device used was non-invasive and employed inductive coupling to read the information travelling through the cable. It would not have been found, except for a US traitor who sold the information to the Soviets.

You can read more about "Operation Ivy Bells" in the article on Nuclear Submarines in SILICON CHIP, December 2016 at: **siliconchip.com.au/Article/10459**

Underwater covert intercepts can be most easily made on undersea cables at regeneration points, ie, locations that contain amplifiers and signal conditioning equipment in which the optical fibres are unbundled. However, logistically, it is still extremely difficult.

It has now been disclosed that most intercepts occur at the land termination stations of cables, with the cooperation of various governments or companies using non-invasive probes on the cable. See the section below on optical fibre tapping.

According to Amnesty International, the UK intelligence agency GCHQ (Government Communications Headquarters) has 40,000 search terms and the US NSA (National Security Agency) has 31,000 terms of interest that they look for when routinely scanning communications over cables or elsewhere.

Micro- and nano-sized aircraft

The CIA developed a remarkable device in 1970, called the Insectothopter. It was a bug (literally) that could fly to its destination, whereupon it was meant to sit and listen (see Figs.25 & 26). It used a hydrogen peroxide motor based on a fluidic oscillator (see the article on Fluidics in the August 2019 issue for more details).

The device was the size of a dragonfly (6cm long, with a wingspan of 9cm) and had a flight time of 60 seconds and a range of 200m. The launch weight was one gram and the device was made by a watchmaker.

But it was found to be unable to withstand even the most minor crosswind, so the project was abandoned.

The audio data it would have collected was transmitted via a laser beam. The same laser beam that was used for audio transmission was also directed at a bimetallic strip in the tail for guidance. While there is little information on the source of this laser, one assumes that it was external to the device and that audio was returned via the laser bouncing off the device, modulating the beam with audio (like a laser microphone).

For more information, see the videos titled *"Official CIA video 'Insectothopter: The Bug-Carrying Bug'"* at: **siliconchip.com.au/link/aasu** and *"The Insectothopter: The CIA's dragonfly spy drone from the 1970s"* at: **siliconchip.com.au/link/aasv**

A more modern take on this idea is the Black Hornet Nano (Fig.27), developed by Prox Dynamics of Norway (now owned by USA company FLIR Systems), a nano-UAS (unmanned aerial system) reconnaissance drone in use by the armed forces and counter-terrorist organisations of the United States, France, the United Kingdom, Germany, Australia, Norway, the Netherlands and India.

This UAS weighs 18g, can fly at a speed up to 18km/h up to 1500m from the controller and can fly for 20-25 minutes and transmit live video, or still images, including night vision.

There is a later version of the device in use by the USA,

Fig.27: an Australian Army soldier with a PD-100 Black Hornet Nano.

Fig.28: this widely-circulated picture is said to be of a "mosquito drone" that can take a DNA sample from a person or leave an RFID device on their skin. While similar devices will almost certainly be available one day, this photo was a conceptual mock-up only, not a real device.

the Black Hornet III, with more advanced video and other capabilities which weighs 32g, with a range of 2000m and a speed of 20-25km/h.

The Nano is extremely expensive, at US$190,000 per kit! For more details, see the video titled *"Introducing the FLIR Black Hornet 3"* at: **siliconchip.com.au/link/aasw**

Buildings bugged during construction

When a new US Embassy was to be built in Moscow, starting in 1979, American negotiators made the colossal mistake of allowing the Soviets to design and build it.

Despite early warnings by US experts about possible or likely bugging, work continued even though the construction work being done was of low quality and plagued with problems.

Starting in 1982, the building was inspected using X-ray and other techniques, and it was found to be riddled with eavesdropping devices and cables built into the structure, including resonating devices that could work indefinitely for years without their own power (as used in "The Thing", described earlier).

There were also many decoy devices.

By 1985, it was becoming apparent that the listening devices couldn't be easily removed and in 1987, it was decided to demolish most of the new building.

It wasn't until 2000 that the matter was fully resolved and a new section of the building designed for classified work was completed. See the video titled *"27th October 1988: Ronald Reagan halts construction of the Moscow embassy"* at: **siliconchip.com.au/link/aasx**

In 1995, the ABC and the Sydney Morning Herald revealed that in a joint Australian/US operation, optic fibre bugging devices of an unspecified nature had been installed during the construction of the Chinese Embassy in Canberra in the 1980s. It seems the Chinese returned the favour when they allegedly stole the plans for the new ASIO headquarters.

Theft of building plans

In May 2013, it was claimed on ABC's Four Corners program that ASIO's new headquarters in Canberra, under construction at the time, was compromised due to computer hackers of Chinese origin stealing plans for the building. This included details of communications cabling, server locations, floor plans and security systems.

These claims were denied by Government spokesmen at the time, but the opening of the building was delayed nevertheless, and Four Corners stuck to its story and the credibility of its source. The original ABC Four Corners program, *"Hacked!"*, can be seen here: **siliconchip.com.au/link/aasy**

Theft of intellectual property and military information

Of course, there are numerous examples of the theft of intellectual property and military information. Here is one example: Adelaide company Codan (**https://codan.com.au/**) make metal detectors and a wide variety of other high-quality equipment including secure radios for the Australian military and our allies.

They had their computers hacked and their intellectual property stolen. The attack apparently involved Chinese hackers who gained access to an executive's laptop after he logged into a hotel WiFi system in China.

They inserted malware specifically designed to target the company's files when the executive returned to Australia. The hackers used the stolen files to make cheap counterfeit copies of their metal detectors, which were sold in Africa. Further information on this hack is available in the same Four Corners video linked above.

Stuxnet

Stuxnet was a malicious computer worm and cyberweapon that was responsible for the partial destruction of Iran's nuclear weapons program in 2010. It was installed on the target computer systems by breaching the "air gap" of the non-network connected systems via an infected USB memory device. The worm worked as follows:

It installed itself in the Windows operating system as a 'rootkit'. This is a malicious program that gets unauthorised access to parts of the operating system that are not usually allowed by normal programs.

This would typically be detected and prohibited, but it installed itself undetected using the stolen private security keys from two highly-trusted companies that write software for Windows. Thus, there were no alarms.

```
HookSomeAPIs    proc near               ; CODE XREF: StartAddress+38↓p
                push    edi
                push    offset dword_1000617C
                push    offset FindFirstW_Hooker
                push    offset aKernel32_dll ; "KERNEL32.DLL"
                mov     edi, offset aFindFirstFilew ; "FindFirstFileW"
                call    HookAPI
                push    offset dword_10006180
                push    offset FindNext_Hooker
                push    offset aKernel32_dll ; "KERNEL32.DLL"
                mov     edi, offset aFindnextFilew ; "FindNextFileW"
                call    HookAPI
                push    offset dword_10006184
                push    offset FindFirstExW_Hooker
                push    offset aKernel32_dll ; "KERNEL32.DLL"
                mov     edi, offset aFindfirstFilee ; "FindFirstFileExW"
                call    HookAPI
                push    offset dword_10006178
                push    offset QueryDirectory_Hooker
                push    offset aNtdll_dll_0 ; "NTDLL.DLL"
                mov     edi, offset aNtquerydirecto ; "NtQueryDirectoryFile"
                call    HookAPI
                push    offset dword_10006178
                push    offset QueryDirectory_Hooker
                push    offset aNtdll_dll_0 ; "NTDLL.DLL"
                mov     edi, offset aZwquerydirecto ; "ZwQueryDirectoryFile"
                call    HookAPI
                pop     edi
                jmp     sub_10001790
HookSomeAPIs    endp
```

Fig.29: a sample of the Stuxnet code.

Fig.30: a Google Earth image of the bin Laden compound. It attracted attention because of its *absence* of communications devices or connections, compared to its neighbours.

Once Stuxnet was installed, it gained access to the PLCs or programmable logic controllers which were connected to the computer and used to control the uranium centrifuges for making weapons-grade uranium.

It then changed the program libraries in the PLCs in a way that if the legitimate operator attempted to change any routine, they would think they had done so, but Stuxnet would continue to operate in the way intended.

This meant that no one could tell that anything was wrong. The new program libraries also prohibited any attempt to read or delete the Stuxnet code, even if it was detected.

Stuxnet sat silently on infected systems for about 30 days, gathering information and preparing for the final attack. It allowed the regular code to run on the PLCs most of the time, but occasionally changed the code. This slow, subtle operation meant that as far as the user was concerned, the system was operating more or less normally, but with a higher number of breakdowns than usual.

Stuxnet destroyed machinery by altering both the speed and pressure of over 5000 uranium centrifuges. Centrifuges which typically operated at constant speed were made to alternately run very fast and then very slow, which interfered with the uranium separation process and also caused long-term damage to the machines.

Stuxnet also caused some pressure relief valves of the centrifuges to remain closed when they should have been open, causing dangerous and destructive over-pressures.

The Iranians suspected nothing until a large number of machines (about 1000) had been destroyed.

For those interested, the Stuxnet code can be viewed at: **siliconchip.com.au/link/aasz** (a snippet is shown in Fig.29). An analysis of how the worm works is at: **siliconchip.com.au/link/aasz**

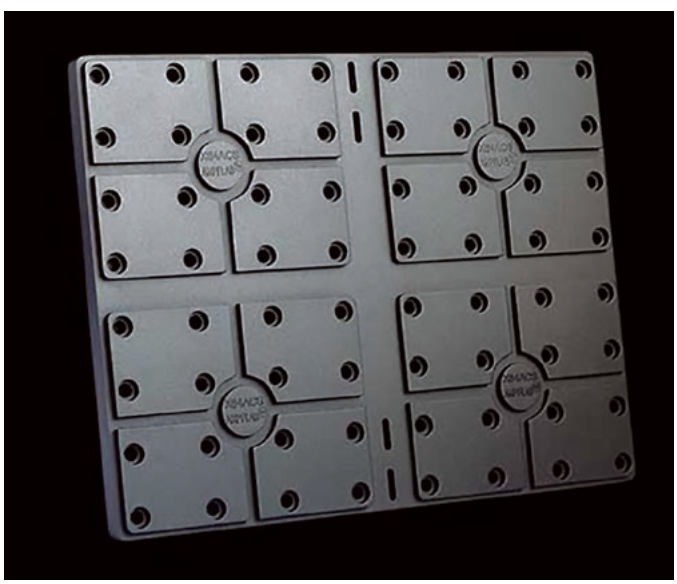


Fig.32: the AMPFLAB (http://ampflab.com/) X64ACS phased-array microphone comprising 64 separate microphones. It is 38cm x 26cm and is claimed to receive human speech at ranges of up to 150m (or greater) without background noise. It has a noiseless acoustic gain of 26dB at 1kHz.

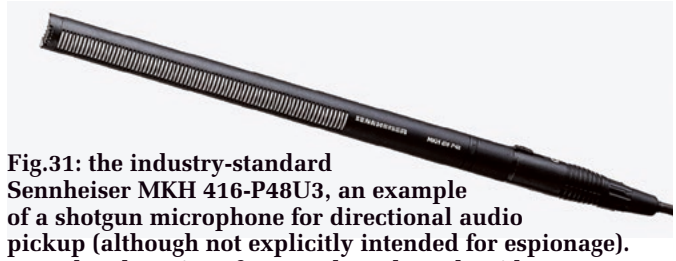


Fig.31: the industry-standard Sennheiser MKH 416-P48U3, an example of a shotgun microphone for directional audio pickup (although not explicitly intended for espionage). Note the phase-interference slots along the sides.

Catching Osama bin Laden

The ex-terrorist Osama bin Laden was extremely paranoid about being bugged or tracked by electronic devices and therefore he did not even wear an electronic watch or use a mobile or satellite phone.

Apart from reports from people "in the field", one of the things that eventually gave away his location was his "presence by absence". In an area of mansions and wealthy homes, his compound was notable for its lack of telephone and internet service (see Fig.30).

Bin Laden is even known to have been concerned that one of his wives might have had a bug implanted in her tooth after a visit to the dentist. But ironically, in the end it wasn't a bug that led to his downfall, it was his extreme paranoia about . . . bugs!

Acoustic microphones

Conversations can be recorded at a distance with an appropriate microphone. Apart from common uses such as recording bird calls, a parabolic dish microphone can be used to record conversations from afar.

But they have poor low-frequency response due to their

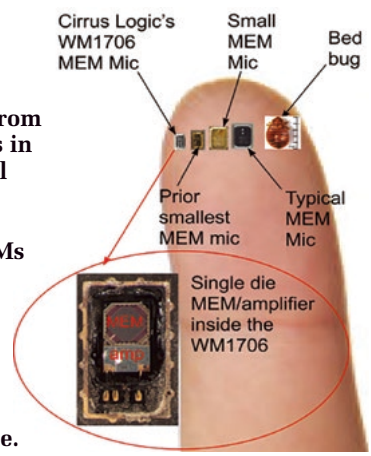


Fig.33: this 2015 photo is from a company that specialises in 'tear-downs' of commercial devices for industrial competitors. It shows the Cirrus Logic WM1706 MEMs (micro-electromechanical system) microphone and associated circuitry for use in portable devices such as phones. It would be suitable for espionage devices due to its small size.

Fig.34: the commercially-available EMAX-3100 remote laser audio monitoring system showing the laser, receiver and computer.

relatively small size compared with the wavelengths of typical speech. Acoustic array, shotgun (Fig.31) or phased array (Fig.32) microphones are alternatives.

Shotgun microphones consist of a long tube where sounds from the intended target arrive directly at the microphone element and unwanted, off-axis sounds are absorbed in the sides of the tube by phase-interference slots. See the educational video on using a shotgun microphone titled *"How To Record Audio - Shotgun Microphone"* at: **siliconchip.com.au/link/aat0**

Microscopic microphones, like the one shown in Fig.33, can be easily hidden. See the section on Bugs below for more details on hidden microphones.

Fig.36: this is claimed to be the world's smallest UHF FM bug, which transmits at 420MHz with a claimed range of 250-300m. It is 15mm in diameter and 5mm thick, including its CR1220 battery, and has a working time of 5-10 hours. The antenna is 10cm long, and it is available on eBay for about $75.

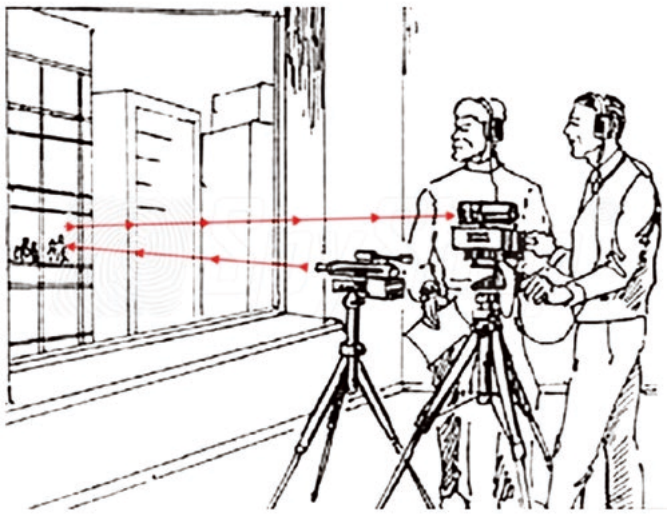


Fig.35: a typical usage scenario for a laser microphone.

Laser microphones

A laser microphone or laser-based listening system is an audio eavesdropping device that uses a laser beam which is directed onto a rigid vibrating object, such as a window pane, at the target location. The audio modulates the reflected beam, which is picked up and converted back to sound at the remote site (see Figs.34 & 35).

The concept was developed by Léon Theremin who used an infrared beam (as mentioned above), before lasers were invented. The system can be defeated by attaching a transducer to a window pane to play music or other noise, masking the conversation, or by playing noise or music in the room to be protected.

The system can be ineffective with rain and snow, and the beam from the laser is detectable. These systems were very popular in the 1980s and 1990s, but less so now with the multitude of other espionage options available.

Bugs

The number of bugs available, both commercial and home-built, are too numerous to list but here are a few common examples. Of course, we don't know much about the bugs used by government intelligence agencies, but they would be at least as capable as these, probably much more so.

Many bugs now also have a SIM card to connect to the

Fig.37: the EDIC Mini Tiny+ A77 is a voice recording device can record continuously for 55 hours and can be activated by a switch, voice activation or by a programmed schedule. It is of Russian origin. One online seller lists it for US$339.

Fig.38: an example of a "Mini GPS Tracker" widely available on eBay, intended to track children and pets. But it could be used to track anything or anyone of interest. A SIM card is put in the device and audio near the device can be heard remotely, plus its location tracked. It can be remotely operated by another phone and is claimed to have a standby time of 12 days and a working time of 4-6 days. This particular example was on eBay for UK£14.99.

mobile phone network, so it is not necessary to receive any direct radio transmission from the device. It is only necessary to dial into the device from anywhere to hear what's going on, subject to enough battery power or a permanent power connection.

Figs.36-40 show five very capable and readily available bugs. Some of them are quite cheap, while others are definitely not (but are very capable).

Bugging the personal possessions of a target is a common espionage method, and bugs have been installed in just about anything you can imagine, including shoes. In 1995, two crooked NSW police offers were famously caught pocketing bribes on a camera hidden in their car dashboard. See: **siliconchip.com.au/link/aat1**

Fig.40: an 800-line colour CCTV camera with audio, disguised as a screw, found on eBay for under AU$20 delivered.

Fig.39: a bug with its own SIM card, to connect to a mobile phone network, hidden in a plugpack.

In a more recent case, last year, a drug dealer was arrested after a hidden camera in his apartment proved that he was selling cocaine. See: **siliconchip.com.au/link/aat2**

To prove that this sort of bugging is nothing new, here's an article from the March 1964 issue of Time magazine about bugging, including video and audio feeds: **siliconchip.com.au/link/aat3**

Bug detectors

There are a very many bug detectors on the market, from very cheap to very expensive (see Fig.41 for one readily available example).

Apart from visual inspections, bugs are typically found by detecting RF emissions (if the bug transmits) or by detecting reflections from camera lenses.

The problem with RF emissions is that the RF spectrum is very busy these days, and it is not always easy to determine whether detected transmissions are legitimate or not. Also, such devices will not detect recording bugs. Non-linear junction detectors (described last month) can detect the presence of electronic devices, but these can be easily defeated, as is done in professional bugs.

Fig.41: a consumer-grade RF and video camera bug detector, this one available from Jaycar. Most simply detect RF emissions given off by bugs; the problem is that more "professional" bugs do not!

We expect that professional bugs would also incorporate measures against the latest detection technologies.

Key loggers (hardware)

Besides malware (ie, surreptitiously installed software with bad intentions), there are numerous hardware USB key logging devices available. These plug into a computer's USB port, internal or external. An external device may not be noticed if it is at the back of a desktop machine.

These devices log the user's keystrokes (with time stamp if desired), and the data can be retrieved by physically removing the device; some devices that can be accessed via WiFi; some are stealth devices disguised as regular cables, Ethernet connectors, keyboard connectors or RS-232 devices.

Some can even emulate the slight movement of a mouse to prevent the computer from going to sleep, presumably to keep the computer susceptible to other forms of attack.

Optical fibre tapping

Fibre tapping or interception of optical fibre communications is another category of cable interception. Contrary to popular belief, if a fibre optic cable is physically accessible, it is relatively easy to intercept communications carried within it if they are unencrypted (or encrypted and the interested party has the tools to decrypt them).

This type of interception will probably never be detected unless someone is specifically looking for some small amount of signal attenuation on the fibre.

Note that one would need a sufficient amount of cable slack and be able to open the cable jacket without damaging any of the fibres contained therein. This requires a bit of skill and good luck.

The intercepted data can then be examined with a network traffic analyser like Wireshark (www.wireshark.org).

See Figs.42&43 and the video titled *"How to Hack an Optical Fiber.wmv"* at: siliconchip.com.au/link/aat4

One example of a significant optical fibre tapping facility is room 641A at the SBC Communications building at 611 Folsom Street, San Francisco.

This room is fed by fibre-optic lines connected via beam-splitters to major Internet backbone networks and therefore has "the capability to enable surveillance and analysis of Internet content on a massive scale, including both overseas and purely domestic traffic" (see Fig.45).

Spy Museums

The International Spy Museum in Washington, DC, is well worth a visit (www.spymuseum.org).

The CIA has its own museum, although it is not open to the public. It can, however, be experienced online at: siliconchip.com.au/link/aat9

The US NSA also has a National Cryptologic Museum located in Maryland. See: siliconchip.com.au/link/aata

Spyscape is a private museum in New York City (https://spyscape.com/).

Other spy museums are listed at: siliconchip.com.au/link/aatb

Sadly, Australia appears to have no espionage-related museums.

DIY Spy

Here are some DIY ideas to demonstrate some general espionage techniques.

Note that 'spying' on someone without their permission is almost certainly illegal in all cases, so only test these ideas with the full permission, knowledge and cooperation of the subject(s).

As for the use of any type of transmitter without the appropriate license, you would have to establish the legality for yourself, although compliant low-power FM transmitters for in-car or in-house use and the like are readily available from major Australian retailers.

- Build the "Sooper Snooper" parabolic dish microphone, described in Silicon Chip, September 2001 (siliconchip.com.au/Article/4152).
- See the distribution of WiFi points in an area and map them, as explained in the video titled *"Building a Camera That Can See Wifi | Part 3 SUCCESS!"* at: siliconchip.com.au/link/aatc
- "See" through walls with a commercially available device, and also detect motion on the other side of the wall. See the video titled *"How To Use Your Smartphone to See Through Walls! Superman's X-ray Vision Challenge"* at: siliconchip.com.au/link/aatd
- Build a bug using the instructions in the video titled *"Let's build the world's smallest Surveillance Spy Bug."* at: siliconchip.com.au/link/aate
- You can buy the world's smallest consumer FPV (first person view) live streaming HD drone, the VIDIUS by Aerix. It can surveil an area of interest, with video transmitted back to the user. It is 4.3 x 4.3 x 2.5cm in size with a battery life of around five minutes. See the video titled *"Smallest FPV drone VIDIUS - World's Smallest FPV Drone by Aerix Drones"* at: siliconchip.com.au/link/aatf
- Build a device which claims to detect if the microphone in your smartphone has been activated by an unauthorised party. See the video titled *"Make your own smartphone spy detector for less than 10$!!"* at: siliconchip.com.au/link/aatg
- Use your computer monitor and a radio to play music, demonstrating how hardware can be used for purposes that it was never designed for, to breach an "air gap". See: siliconchip.com.au/link/aath and the video at: siliconchip.com.au/link/aati
- Build your own laser microphone, using the instructions at siliconchip.com.au/link/aatj or siliconchip.com.au/link/aatk
- Also see the videos titled *"Fast Hacks #6 - Laser Spy Microphone"* at: siliconchip.com.au/link/aatl and *"Laser Spy PhotoResistor test"* at: siliconchip.com.au/link/aatm
- Browse the large archive of material on passive resonant cavity devices at the following link, including quotes from "Spycatcher": siliconchip.com.au/link/aatn

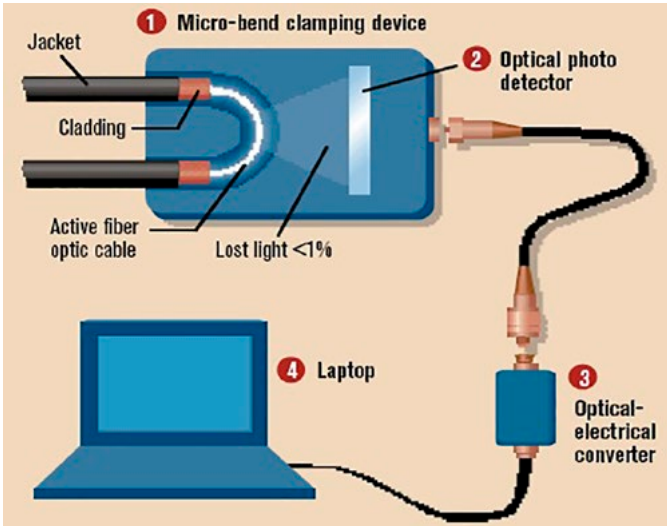


Fig.42: a means by which optical fibres are non-invasively tapped. The cladding is exposed, a partial loop is created and a small amount of light leaks from the loop (1%), which is then read by a photo-detector and appropriate software.

Fig.43: the commercially-available FOD 5503 non-invasive clip-on coupler for bi-directional coupling into 25-micron coated single-mode fibres. It has legitimate purposes for testing, cable identification and linking into cables where no termination is available but could also be used for espionage.

As of 2006, it was believed to contain a NarusInsight supercomputer which can analyse internet data streams and track individual users to determine what they are doing, including checking the content of emails and messages. It can also make associations between users who visit certain websites and/or use certain words or phrases in their emails or messages.

It can monitor the combined traffic of several million broadband users and the software can store their internet activity for later analysis. Note, that was in 2006 and revealed only due to an Electronic Frontier Foundation lawsuit. One wonders what the capability is today!

Range-R through-wall radar

The Range-R from L3 Technologies (Fig.46) is a through-wall radar for police and military use that can detect the range and number of people behind a solid non-metallic wall. It does not show images of people, but is akin to an advanced wall-stud finder that indicates the number of people and their range, and even their rate of breathing, from behind a brick or concrete wall.

It uses the Doppler effect to sense motion, stepped-frequency continuous-wave radar technology and proprietary target detection algorithms. It is said to be in use by 50 US police departments and has raised legal controversy about its warrantless use. See the video titled "Police surveillance: Privacy invading Range-R radar gives cops ability to 'see' through walls" at: **siliconchip.com.au/link/aat5**

Using WiFi signals for through-wall imaging

Researchers at the Computer Science and Artificial Intelligence Laboratory (CSAIL) at the Massachusetts Institute of Technology (MIT) have been able to use WiFi-like signals to observe people through plasterboard ('Gyprock') walls, although the imagery is very blob-like – see Fig.44.

They have used artificial intelligence to turn the resulting blobs into stick figures resembling a person. See the video titled *"AI Senses People Through Walls"* at: **siliconchip.com.au/link/aat6** and *"Seeing through walls - MIT's Lincoln Laboratory"* at: **siliconchip.com.au/link/aat7**

Researchers at CSAIL have also produced human-like imagery through walls. They used a system with 13 transmitting antennas and eight receiving antennas operating in the S-band (2-4GHz) to image at people on the other side

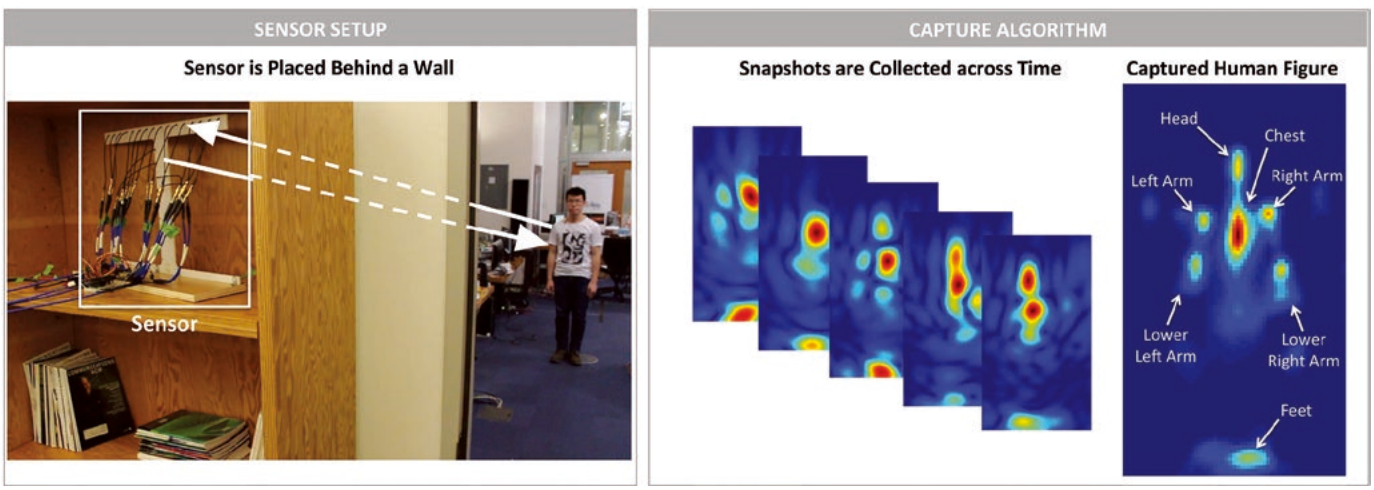


Fig.44: the results of through-wall imaging in the S-band by the MIT Lincoln Lab system. Even though the images don't resemble actual people, they can be used to determining the number and location of those present.

Fig.45: Room 641A at the SBC Communications building at 611 Folsom Street, San Francisco. It is a 7.3m x 14.6m facility run by the US National Security Agency and is fed by fibre-optic lines connected via beam-splitters to major Internet backbone networks. *Image credit: Mark Klein, Creative Commons Attribution-Share Alike 3.0 Unported License.*

of solid concrete walls at 10.4 frames per second.

The system is described as an ultra-wideband multiple-input multiple output (MIMO) phased array radar. The RF received from the target is only 0.0025% of the transmitted signal, and the range of the system is about 20m from the wall. An application of this is for military or intelligence use to see the number and location of individuals in a building.

See Fig.47 and the video titled *"Capturing a Human Figure Through a Wall using RF Signals"* at: **siliconchip.com.au/link/aat8** SC

Fig.46: the Range-R through-wall hand-held radar unit

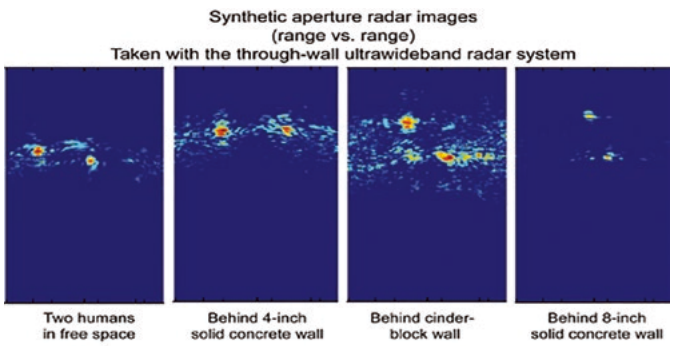

Synthetic aperture radar images
(range vs. range)
Taken with the through-wall ultrawideband radar system
Two humans in free space
Behind 4-inch solid concrete wall
Behind cinder-block wall
Behind 8-inch solid concrete wall

Fig.47: here, CSAIL researchers are demonstrating detecting the location and movement of people through plaster walls using 2.4GHz radar.

~~Jack~~ Hack in a Box: Warshipping, where the packaging IS the spy!

As we went to press, a report appeared on the Ars Technica website (**www.arstechnica.com**) about a new development in industrial espionage: "warshipping".

You'd probably be aware of the term "WarDriving" where people drive around searching for vulnerable WiFi networks they can tap into.

Warshipping is different: it involves hiding the search device inside packaging that is legitimately being delivered to a target.

Not just in the box, it's actually built **inside the cardboard walls** of the package. Hidden circuitry (much of it off-the-shelf) is secreted which will find vulnerabilities in the target's wireless network, hack into them then start transmitting secrets using, for example, a built-in cellular phone modem.

Many organisations have very strict rules about bringing mobile phones onto their premises in order to maintain tight security. But those same companies wouldn't think twice about a courier turning up with a delivery for Mr .....

It goes to show just how much trouble people will go to when they believe the information they seek is worth the effort!

Using less than $100 worth of gear—including a Raspberry Pi Zero W, a small battery, and a cellular modem—IBM's X-Force Red team assembled a mobile attack platform that fit neatly within a cardboard spacer they dropped into a shipping box. It could also be embedded in objects such as a stuffed animal or a plaque.

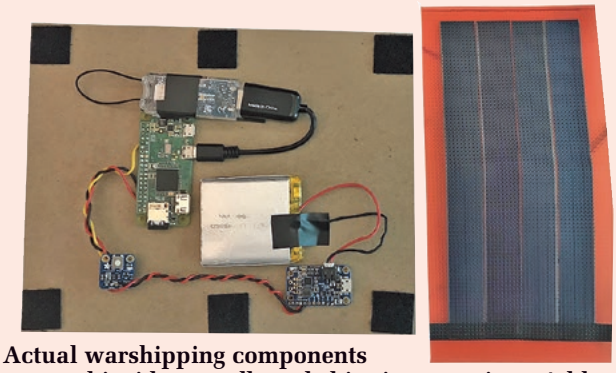
X-Force head Charles Henderson noted. "The thing that's cool about this is, this is the wall of the box. It can be easily built into the cardboard. If you get a phone shipped to you, you're suspicious of it."

But no-one would (at least until now!) be suspicious of the box that phone came in. Or in a myriad of other devices – even things like WiFi routers or wall-mounted power supplies with "hidden extras."

Even companies who routinely open and inspect deliveries can be (and have been) tricked into accepting a warshipping package. Even if they thoroughly examine the contents, they don't suspect the box itself!

There's a lot more information in the Ars Technica story – it's well worth a read.

You can get to it via **siliconchip.com.au/link/aauz**



Actual warshipping components secreted inside a cardboard shipping container. Add the solar panel at right and the system will keep on sending information as long as it's not discovered.

HIGH POWER
VARIABLE LIN

We've been promising this project for a while! However, it has taken some time to get it just right.

But it's finally here.

This power supply can deliver up to 45V at up to 8A, or up to 50V at lower currents. It has a fully adjustable output voltage down to 0V and an adjustable current limit. Its operating envelope is shown in Fig.1.

That makes it suitable for many different tasks, including testing newly built or repaired equipment, temporarily running various devices, charging batteries etc.

Its controls are simple. Two knobs set the voltage and current limits, and the power supply maintains its outputs within these constraints.

It shows the actual output voltage, set voltage, actual current, set current and heatsink temperature on an LCD screen.

These can be shown on an alphanumeric LCD, or if you prefer, you could use separate LED or LCD panel meters.

It has a pair of internal high-speed fans to keep it cool. These automatically spin up and down as required. If the Supply is operated in the orange shaded area shown in Fig.1, or at very high ambient temperatures, or the fans fail, a thermal current limit comes into play. This reduces the output current until the unit cools down, preventing damage to the Supply.

While we originally planned for this power supply to be able to deliver 50V at 8A, it is difficult to achieve that with a practically sized transformer and a reasonable parts budget. It's limited to

- 45V/8A EAR SUPPLY

Part 1 - by Tim Blythman

This adjustable bench supply can deliver heaps of power, up to 360W in total, making it ideal for the test bench or just general purpose use. It can operate as a voltage or current source at 0-45V and 0-8A. It is an entirely linear, analog design. It's fan-cooled with automatic fan speed control, short circuit/overload protection and thermal self-protection. It can even be used as a basic but powerful battery charger.

Features & specifications

- Up to 45V output at 8A, 50V output at 2A (see Fig.1)
- Low ripple and noise
- Adjustable output voltage, 0-50V
- Adjustable output current, 0-8A
- Constant voltage/constant current (automatic switching)
- Shows set voltage/current, actual voltage/current and heatsink temperature
- Fan cooling with automatic fan speed control
- Thermal shutdown
- Fits into a readily available vented metal instrument case
- Switched and fused IEC mains input socket
- Uses mostly commonly available through-hole components

45V at 8A because despite using a large 500VA transformer, its output voltage still sags significantly under load, meaning there isn't enough headroom for regulation.

However, if the transformer was upgraded (and possibly the filter capacitors too), it could be capable of delivering 50V at 8A.

Design overview

The basic design of the Bench Supply is shown in the simplified circuit diagram, Fig.2. It's based around an

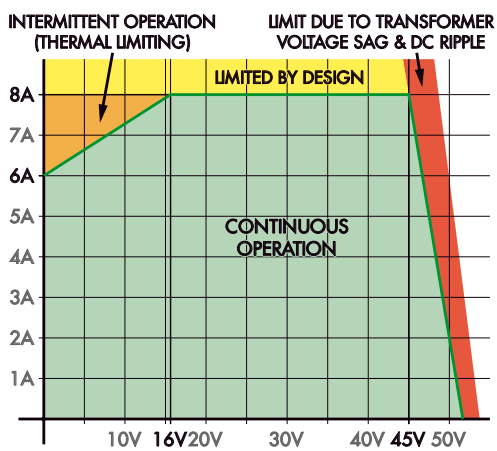


Fig.1: the Bench Supply can deliver 8A but can only do so continuously with an output voltage of between 16V and 45V. Below 16V, internal dissipation is so high that the unit will go into thermal limiting after a few minutes. Above 45V, transformer regulation means that the DC supply voltage drops far enough that 100Hz ripple starts appearing at the output, so the actual voltage may be lower than the set voltage.

Here's a teaser look inside our new Bench Supply, taken before we applied the dress panel. Full construction details will begin next month. As you might expect from its specifications, there's a lot to this supply, dominated by the 500VA transformer at left. But the good news is that it uses mostly through-hole components so construction isn't too difficult.

LM317HV high-voltage adjustable regulator, REG3. The LM317HV variant can handle up to 60V between its input and output, at up to 1.5A.

Clearly then, this regulator cannot pass the full 8A output current. And even if it could, it couldn't dissipate the 400W that would be required (50V x 8A) as it's in a TO-220 package.

Therefore, the regulator itself only handles about 10mA of the load current, with the rest being delivered by four high-power current boosting transistors, Q4-Q7.

Power is fed into the supply via the IEC input socket shown at upper left, and passes through the mains switch and fuse before reaching the primary of transformer T1.

Its two 40V AC secondary windings are connected in parallel and then on to bridge rectifier BR1 and a filter capacitor bank, generating the nominally 57V DC main supply rail.

This passes to the input of REG3 via a resistor, and also to the collectors of the NPN current-boosting transistors and the emitter of PNP control transistor Q3.

As the current supplied by REG3 rises, Q3's base-emitter junction becomes forward-biased, and it supplies current to the bases of Q4-Q7, switching them on.

As REG3 draws more current, they switch on harder, providing more and more current to the output of the supply. These transistors therefore supply virtually all of the maximum 8A output current

Regulator control

Like most adjustable regulators, REG3 operates by attempting to maintain a fixed voltage between its output (OUT) and adjust (ADJ) pins. In this case, around 1.2V.

Usually, a resistor is connected between OUT and ADJ, and another resistor between ADJ and GND, forming a divider.

As the same current flows through both resistors, the voltage between ADJ and GND is fixed, the regulator output voltage is that voltage plus the 1.2V between OUT and ADJ.

But in this case, rather than having a fixed or variable resistor from ADJ to GND, we have transistors Q1 and Q2, connected in parallel. Their bases are driven from the outputs of op amps IC1a & IC1b. Their emitters go to -5V so that the ADJ pin can be pulled below ground, allowing the regulator OUT pin to reach 0V.

This is important both to allow low output voltages and for the current limiting to be effective.

Op amp IC1a compares the voltage from the wiper of the VOLTAGE SET potentiometer to a divided-down version of the output voltage. It provides negative feedback so that if the output voltage is higher than the setpoint, Q1 is driven harder, pulling the ADJ pin of REG3 down, reducing the output voltage.

And if the output voltage is too low, Q1's base drive is reduced, allowing REG3 to pull the output up.

A capacitor from the ADJ pin of REG3 to the -5V rail helps to stabilise this arrangement. Current control op amp IC1b and its associated transistor Q2 work similarly, to regulate current. Because transistors Q1 and Q2 can only sink current, the output voltage will be determined by which is lower: the voltage setting, or the voltage required to achieve the desired current setting.

The output current is monitored via a 15 milliohm shunt between the output of REG3/Q4-Q7 and the output terminal. Voltage feedback comes from the output side of this resistor, so the supply will automatically compensate for the shunt's voltage drop (up to 120mV).

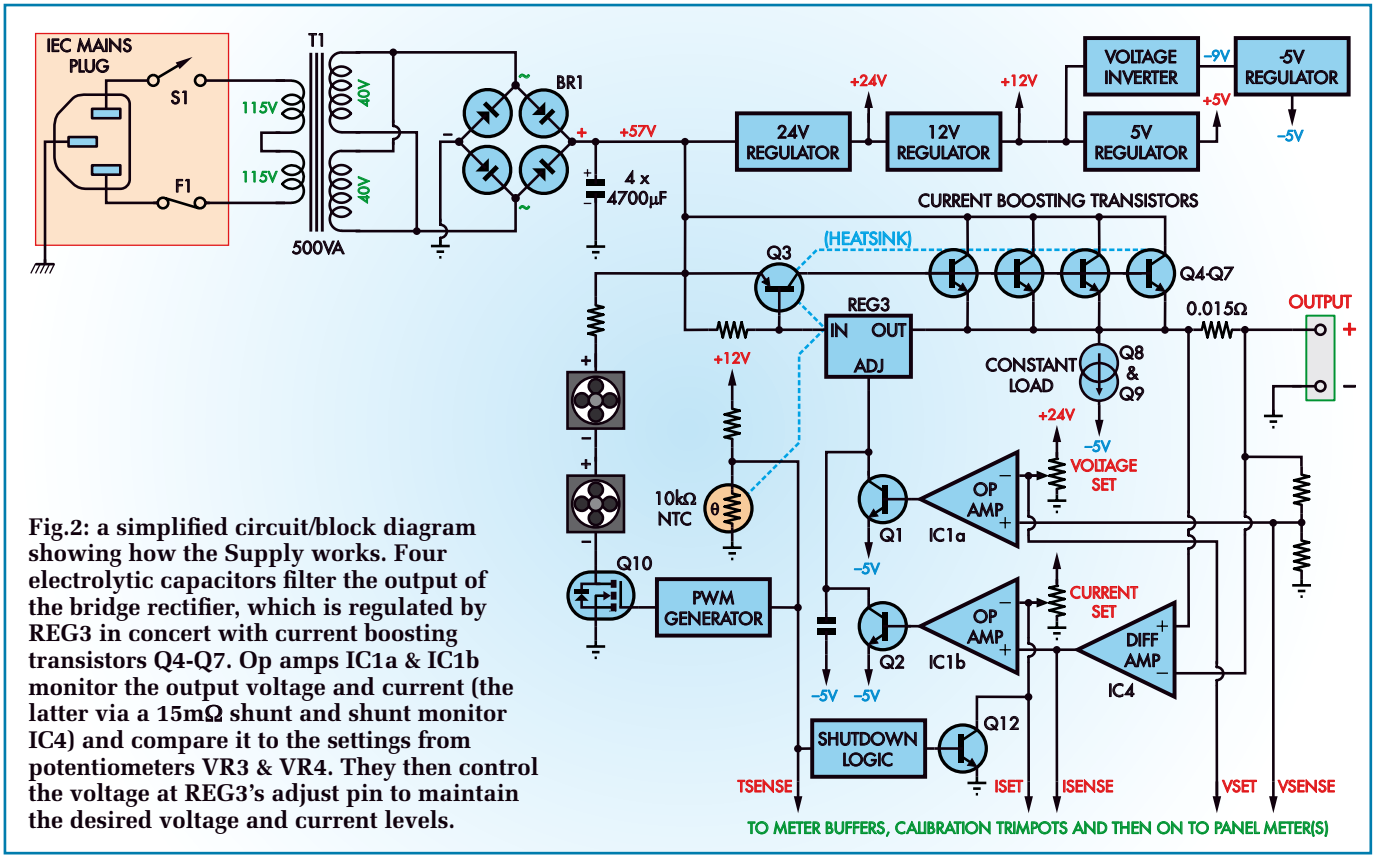


Fig.2: a simplified circuit/block diagram showing how the Supply works. Four electrolytic capacitors filter the output of the bridge rectifier, which is regulated by REG3 in concert with current boosting transistors Q4-Q7. Op amps IC1a & IC1b monitor the output voltage and current (the latter via a 15mΩ shunt and shunt monitor IC4) and compare it to the settings from potentiometers VR3 & VR4. They then control the voltage at REG3's adjust pin to maintain the desired voltage and current levels.

Shunt monitor IC4, a form of differential/instrumentation amplifier, converts the voltage across the shunt to a ground-referred voltage so that IC1b can compare it to the voltage from the current set pot.

By using control voltages to set the desired output voltage and current, we can easily show these on the front panel of the meter, so you can see what you're doing.

LM317-type regulators have a minimum output load current, which is provided by a constant current sink comprising transistors Q8 and Q9.

Otherwise, the output of REG3 would rise of its own accord. The current sink dissipates a lot less power than a fixed resistor would, as the resistor would draw much more current at high output voltages.

The NTC thermistor on the heatsink forms a divider with a resistor such that the voltage at their junction drops as the temperature increases.

This voltage is fed to a PWM generator which increases the duty cycle fed to the gate of Mosfet Q10 as the temperature increases, speeding up the two 24V fans.

The fans are connected in series and run from the 57V supply rail via a dropper resistor. This is a much more power-efficient arrangement than running the fans from one of the regulated rails.

The temperature signal is also fed to control logic which biases NPN transistor Q12 on if the heatsink gets too hot, pulling the current control signal to ground and shutting down the supply.

Several internal regulators are shown in Fig.2, at upper right. These are required to generate various internal control voltage and to power the control circuitry itself.

The output of the +12V regulator is fed to a capacitor charge pump (IC3) which generates a roughly -9V rail that is then regulated to -5V.

As mentioned earlier, this is needed to allow the supply output to go down to 0V.

Thermal considerations

One of the biggest challenges when designing this supply was keeping it cool without needing a huge heatsink in a massive case. The worst case is when the output is short-circuited at 8A (or it's delivering a very low output voltage at 8A). The required dissipation is then over 400W, and it should ideally handle this continuously.

Three things became apparent during testing:

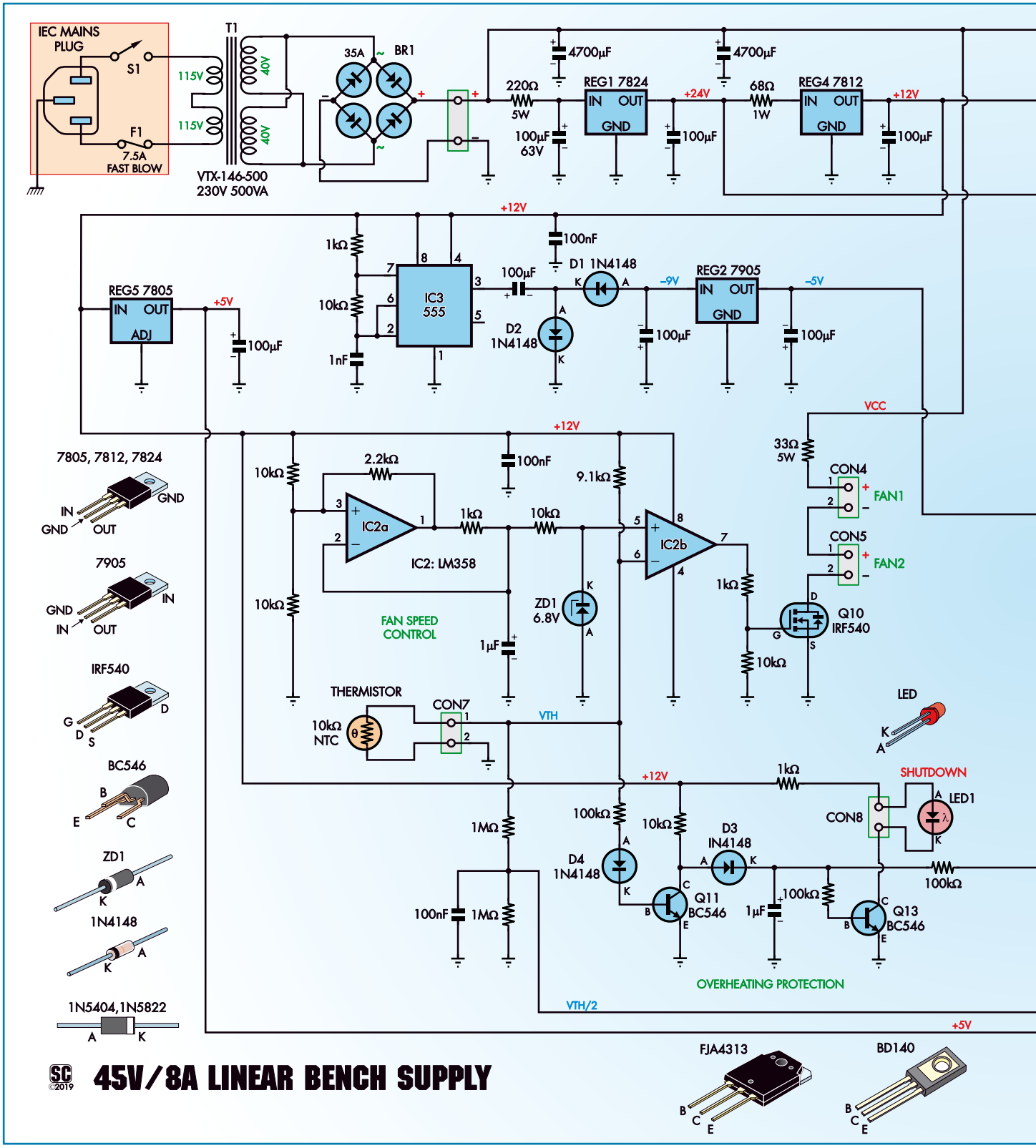
1) The current boosting transistors needed to be mounted on the heatsink with as little thermal resistance as possible, to keep the devices themselves at a reasonable temperature when dissipating around 100W each.

2) To keep the heatsink and case size reasonable, powerful cooling fans are required. These should be thermally throttled to keep noise under control.

3) The case would need to be vented, with careful attention paid to the airflow paths. We also determined that the current boosting control transistor, Q3, would need to dissipate over 1W so it too would need to be mounted on the heatsink, along with REG3 and the bridge rectifier, which also dissipates a significant amount of heat at full power.

Because the heatsink is connected to the collectors of Q4-Q7, which are sitting at 57V, it needs to be isolated from the Earthed case, so we came up with a mounting arrangement that achieved this, while still keeping the heavy heatsink nicely anchored.

The fans are sandwiched between the rear of the case and the heatsink, so they draw air through large holes in the rear panel and blow it straight



SC ©2019 **45V/8A LINEAR BENCH SUPPLY**

over the heatsink fins. That air then turns 90° and exits via the pre-punched vent holes in the top and bottom of the case.

This does an excellent job of getting all that heat out of the relatively small enclosure.

Circuit details

The full circuit of the Bench Supply is shown in Fig.3. While it's considerably more complicated than the simplified diagram (Fig.2), you should be able to see how the various sections correspond.

Starting where power enters the input, the 230V AC mains from the input socket/switch/fuse assembly is applied to the two 115V primary windings of 500VA transformer T1, which are connected in series.

The 40V AC from its paralleled secondaries goes to BR1,

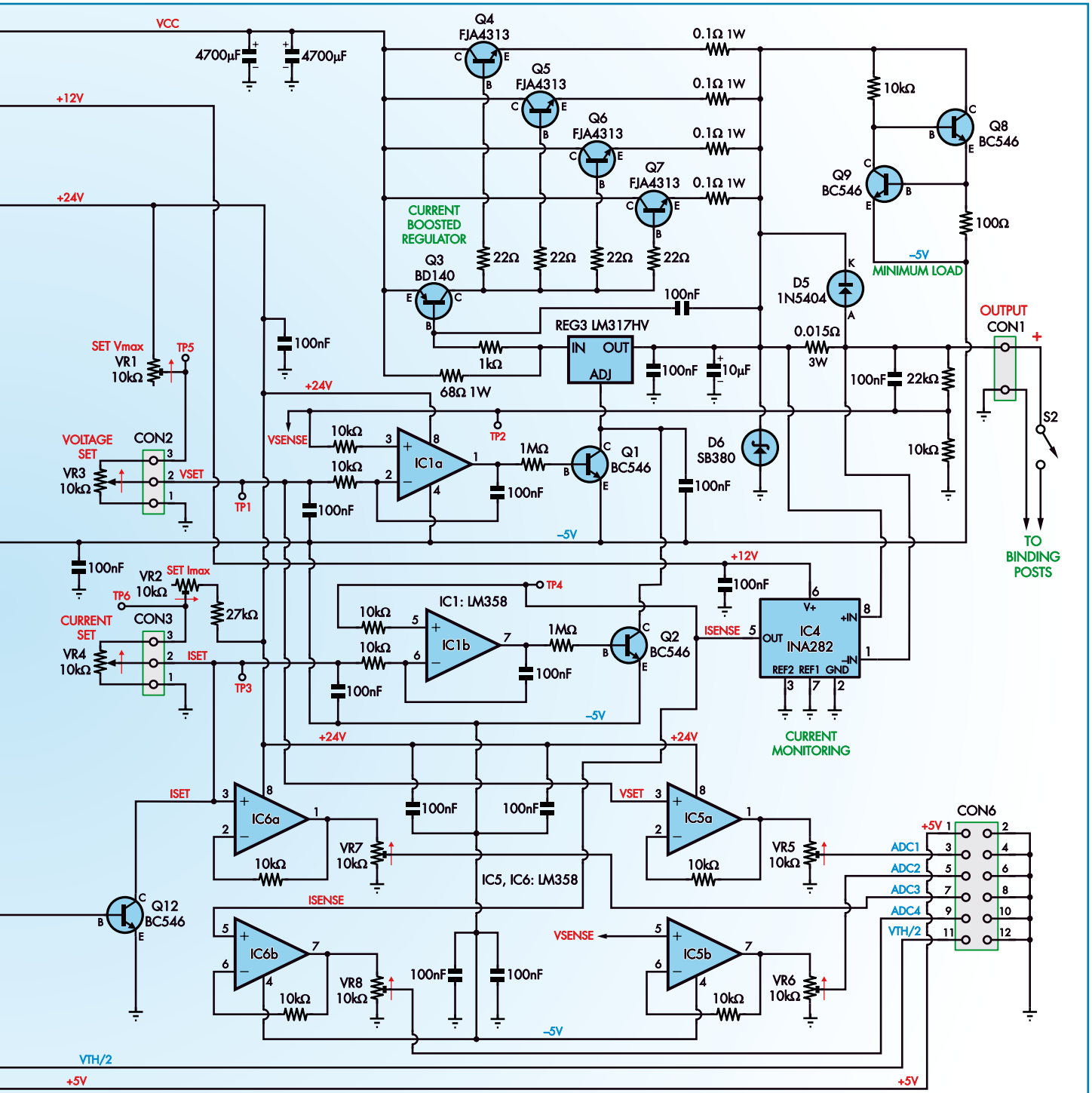


Fig.3: the full circuit of the Bench Supply. The regulator, control circuitry and output current monitoring are in the upper right quadrant, while the panel meter display buffer circuitry is at lower right. At centre left is the PWM fan control, with the thermal shutdown and temperature monitoring circuitry below. The mains power supply, linear regulators and negative rail generator (IC3 & D1-D2) are at upper left.

a 35A bridge rectifier and from there, to a bank of four 4700µF 63V electrolytic capacitors to carry the circuit over the troughs of the mains cycle.

With no load, the main DC bus capacitors sit at around 57V. The diode drop across the bridge is offset by the transformer's no-load voltage being slightly above nominal. In any case, it is just below the 60V limit of the LM317HV regulator (REG3).

Control circuitry

As mentioned earlier, the LM317HV adjustable voltage regulator (REG3) is the core of the circuit. It maintains the output voltage steady in spite of changes in load impedance and current draw, as long as its ADJ pin voltage is held constant. The ADJ pin is pulled up by an internal current from the input. To regulate the output, the circuit sinks a variable current from the ADJ pin.

This control is exerted by IC1, a dual op amp which runs from a 29V supply, between the +24V and -5V rails. The negative voltage is necessary because the LM317HV's ADJ pin needs to be around 1.2V below the output to regulate correctly. To achieve 0V at the output means that the ADJ pin needs to be around -1.2V relative to GND.

The voltage and current control sections of the circuit around IC1 are quite similar. The reference voltage from the potentiometers is fed into their respective op amp inverting inputs (pins 2 and 6) via 10kΩ resistors while feedback voltages from the output are fed into the non-inverting inputs (pins 3 and 5) via another pair of 10kΩ resistors.

The user controls the Bench Supply via voltage set potentiometer VR3 and current set potentiometer VR4. One end of each is connected to ground so that when set to their minimums, their wipers are at 0V which corresponds to zero voltage and current at the output.

These are set up as voltage dividers, and both have series 10kΩ trimpots (VR1 and VR2) connected as variable resistors on their high side. This allows you to adjust their full-scale ranges.

The current setting pot also has a 27kΩ resistor in its divider chain, as the voltage and current adjustment have different scales.

The supply's output voltage is sampled by a 22kΩ/10kΩ voltage divider, with a 100nF capacitor across the upper resistor to give more feedback on transients, stabilising the feedback loop. The result is a 0-15.625V feedback voltage for a 0-50V output voltage.

This divider is necessary to keep the feedback voltage within the input voltage range of op amp IC1a, which runs from the 24V supply.

For the normal 0-50V output range, VR1 is adjusted to give 15.625V at TP1 with VR3 rotated fully clockwise (the voltage at TP5 should be similar). If you want to limit the voltage output to 45V, avoiding the loss of regulation at higher current settings, it can be adjusted to 14.04V instead.

Current feedback from the 15mΩ shunt is via the INA282 shunt monitor, IC4, which has a gain of 50 times.

That means that a 1A output current results in 750mV (1A x 15mΩ x 50) at output pin 5 of IC4. So at the maximum output current of 8A, we get 6V from IC4.

Therefore, VR2 is adjusted to give 6V at TP3 with VR4 rotated fully clockwise (the voltage at TP6 will be similar).

Under normal operation, it is expected that TP2 ("V_{SENSE}") will track TP1 ("V_{SET}") as the output voltage follows the control. If current limiting is occurring, then TP4 ("I_{SENSE}") will track TP3 ("I_{SET}"), and the voltage at TP2 will be less than TP1.

There are 100nF capacitors from the wipers of VR3 and VR4 to -5V, keeping the impedance of these control lines low, to minimise noise pickup which would otherwise make its way to the supply's output.

Getting back to the control circuitry, the output from each op amp stage in IC1 (pins 1 and 7) controls NPN transistors Q1 and Q2 via two 1MΩ base current-limiting resistors. We're using BC546s because they have a 65V rating and they can see up to about 50V on their collectors.

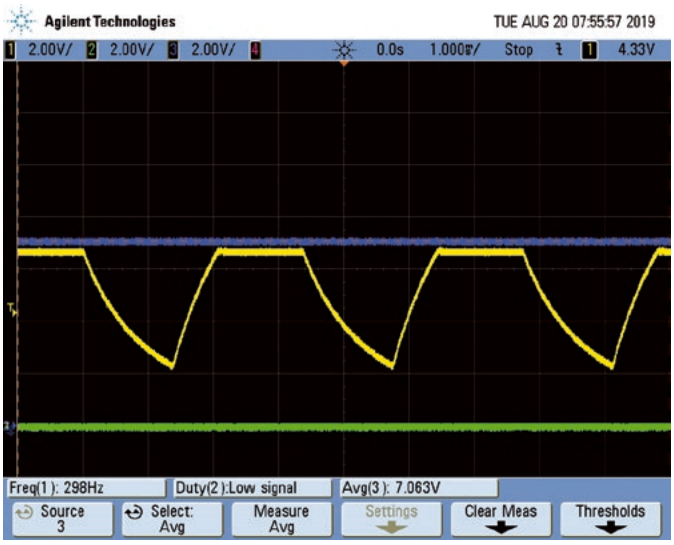
The LM317HV only sources about 10µA out of its ADJ pin, meaning its output can only rise by 1V per millisecond as this current must charge up the 100nF capacitor between the ADJ pin and -5V. However, Q1 and Q2 can discharge this capacitor more quickly, which is important in case the output is overloaded or short-circuited, as it means the supply's voltage can be cut quickly.

Op amp IC1 and transistors Q1 & Q2 combine to provide a phenomenal amount of gain in the control loop, which is handy to have for fast response, but needs to be carefully controlled to avoid oscillation due to overshooting. The minuscule base current through the 1MΩ resistors is one way the response of the loop has been tempered.

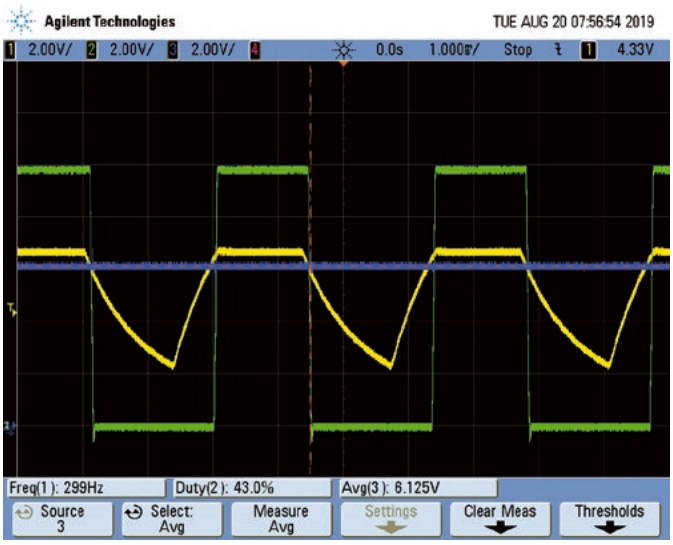
Another is the use of the 1nF and 100nF capacitors between the op amp inputs and outputs, which dampen what would otherwise be a sharp response to a more gradual change, thus preventing oscillation.

Power output stage

As we noted earlier, the LM317HV does not carry most of



Scope1: the yellow trace is the clipped 'triangle' waveform at pin 5 of IC2b while the blue trace is the thermistor divider voltage at pin 6. Since the latter is above the former the whole time, the gate of Mosfet Q10 (green) is sitting at 0V, and so the fans are both switched off.



Scope2: the thermistor temperature has now risen enough that the divider voltage (blue) is now just below the peaks of the clipped triangle waveform (yellow) and so the gate of Q10 (green) is now a 300Hz square wave with a duty cycle of 43%. The fans are now both running at a moderate speed.

The thermal equation

You might notice some parallels between this High Power Bench Supply board and a power amplifier.

Many of our power amplifiers, such as the Ultra-LD Mk.2-Mk.4 series and more recently, the SC200 (January-March 2017; siliconchip.com.au/Series/308) also use a 40V transformer to provide nominal 57V rails and use four power transistors in their output stages.

While this circuit definitely has similarities with a power amplifier, the thermal and power considerations are significantly different.

An audio amplifier only has to deal with a relatively small load impedance variation, delivering its power into 2-10Ω or so, depending on the speaker characteristics and frequency.

The output current therefore varies more or less proportionally with the voltage. So the maximum power dissipation in the amplifier therefore occurs when the output voltage is half the supply voltage – see Fig.4(a).

On the other hand, our High Power Bench Supply PSU cannot expect a fixed load impedance and must be capable of delivering the full load current with zero output voltage. So for the same maximum current, the maximum power is doubled, to over 400W – see Fig.4(b).

Therefore, our design needs to be able to dissipate much more power than a typical audio amplifier module under worst-case conditions.

We initially mounted our power transistors on the heatsink using insulating pads but found that even at modest power outputs, the transistors tended to overheat, even though the heatsink was not that hot. Even switching to a thin layer of polyimide tape did not help significantly.

It was only when we directly mounted the transistors on the heatsink that we were able to keep them at a reasonable temperature when dissipating close to 100W per device.

The thermal resistance of the heatsink (with natural convection only) is quoted as 0.72°C/W, meaning that we would expect a temperature rise of 288°C above ambient with 400W total dissipation. As the maximum operating temperature of the transistors is specified as 150°C, forced cooling is necessary.

The final solution of mounting the output transistors to the heatsink, insulating it from the chassis and having two high-power fans blowing directly over its fins is necessary for correct operation of the unit under heavy load.

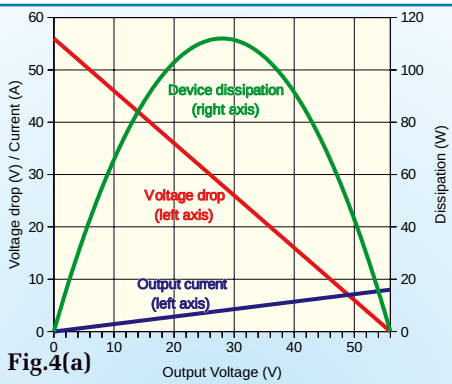


Fig.4(a)

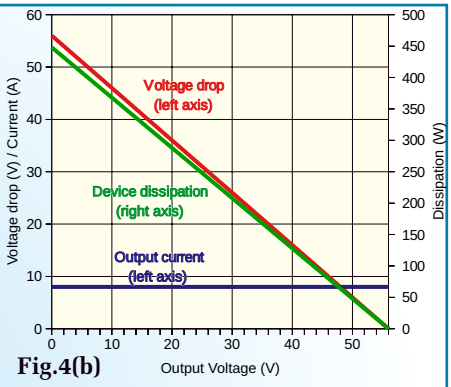
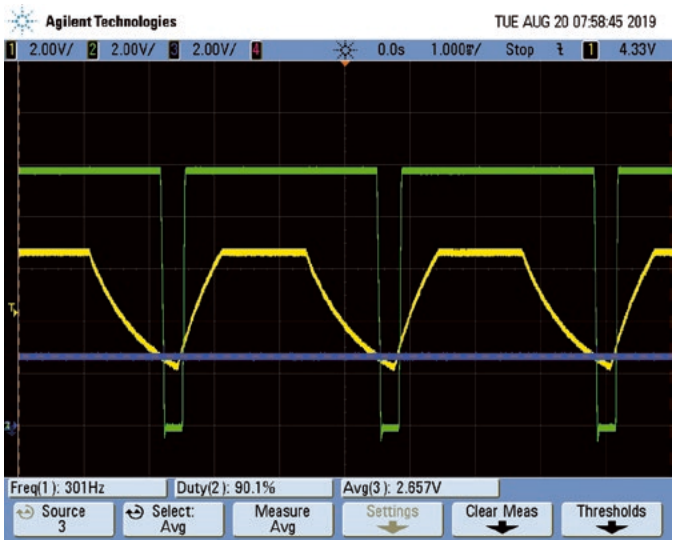


Fig.4(b)

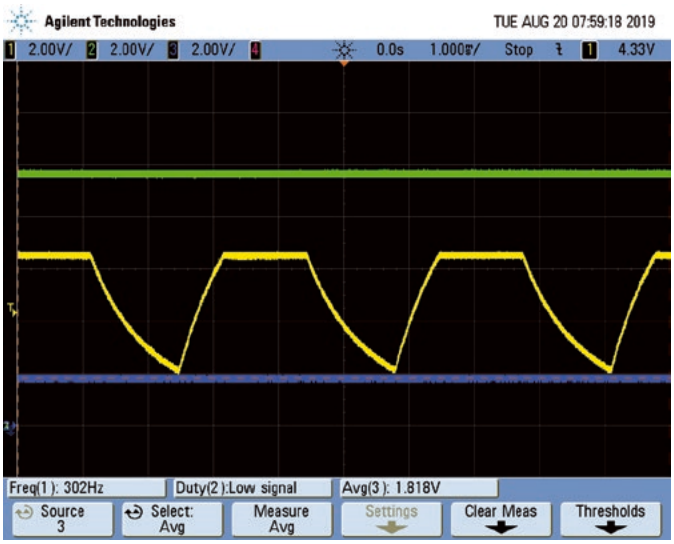
the load current. It is supplemented by four power FJA4313 power transistors, Q4-Q7.

These are controlled by a 68Ω pass resistor on the LM-317HV's input. As its output current rises above 10mA and the voltage across the 68Ω resistor exceeds 0.6V, Q3 switches on and so do Q4-Q7, supplementing the output current.

This situation is stable in that if the output current through REG1 drops due to the output transistors sourcing more current than necessary, the base current through Q3 is automatically reduced and so transistors Q4-Q7 start to switch off. Each of these transistors has a 0.1Ω emitter resistor to improve current sharing even if the device characteristics are not identical.



Scope3: the thermistor temperature has increased significantly, and the divider voltage (blue) has fallen, so the duty cycle at the gate of Mosfet Q10 has risen to 90%.



Scope4: the thermistor divider voltage has now fallen further as the thermistor is very hot (above 80°C) and so the gate of Mosfet Q10 is permanently high, with the fans running continuously at full speed.

At the maximum 8A output current, each of these transistors only passes about 2A, so the loss across these emitter resistors is only about 200mV.

This transistor current booster stage again provides a tremendous amount of gain which needs to be dealt with carefully. A 100nF capacitor connects from the junction of the current sharing resistors back to the base of Q3. This provides negative feedback at high frequencies, preventing oscillation.

Transistors Q3-Q7 and REG1 (the LM317HV) are mounted on the main heatsink.

As we noted, REG1 does not dissipate much power, but it is capable of thermal shutdown.

It should not get hot enough for this to occur, but it does form a 'last-ditch' safeguard.

The 15mΩ high-side current shunt is monitored by IC4, an INA282 high side shunt monitor. IC4 and the shunt are the only two surface-mount devices used in the circuit. IC4 takes the difference between its two input voltages (the voltage across the shunt) and multiplies it by 50 before shifting it to be relative to the average voltage on its REF pins, which in this case are both connected to GND.

Thus we have a voltage proportional to the current and referred to GND, which we can compare to the voltage on the current set potentiometer (VR4).

A 10µF capacitor from the output of REG3 to ground provides some smoothing and stability.

It is purposefully a small value to limit the current in case the output is short-circuited and to ensure a fast response to voltage and current changes when the supply's load is light. It's paralleled with a 100nF capacitor for better high-frequency performance.

Minimum load

The LM317HV requires a minimum output current of around 3.5mA to maintain regulation. Otherwise, the output voltage will rise.

As we cannot guarantee that there will be a load connected to the supply, we have to provide one. In a fixed voltage application, a resistor would be adequate, but not in this case.

To ensure a minimum current is sunk across the full voltage range, a constant current configuration with a pair of BC546 transistors (Q8 and Q9) is used, with the current set by a 100Ω resistor to around 6mA.

Again BC546s have been chosen to withstand the output voltage of up to 50V.

This circuit does not work unless there is more than 1.2V between its top and bottom due to the forward voltage of the two base-emitter junctions. The current is therefore sunk into the -5V rail, to ensure that regulation is maintained, even at low output voltages.

At high voltages on the output, this part of the circuit can dissipate a few hundred milliwatts.

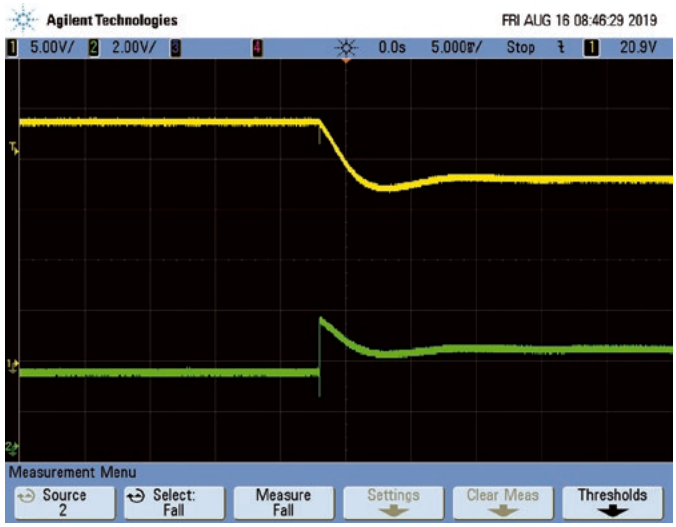
Fan control

A thermistor-controlled fan circuit is provided so that the powerful cooling fans only operate as needed. The thermistor is also used to reduce the output current in case the heatsink gets too hot despite the fans running at full blast.

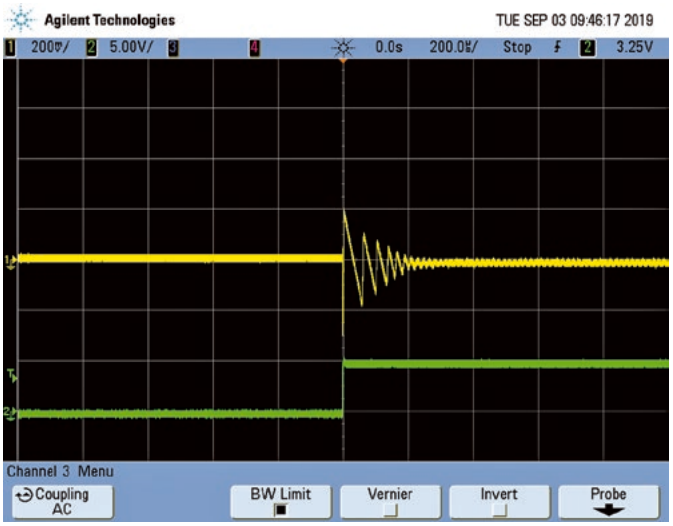
Dual op amp IC2 is powered from the 12V rail. One half of the op amp (IC2a) is a triangle waveform generator, with the 1µF capacitor alternately charged and discharged between around 3V and 9V.

The triangle waveform does not have linear ramps (they're exponential), but that doesn't matter for our application. With timing components of 1kΩ and 1µF, the circuit oscillates at around 280Hz.

The triangle wave from pin 1 of IC2a is fed to the cathode of zener diode ZD1 via a 10kΩ resistor. This creates a truncated triangle wave (see Scope1), which is fed to the non-inverting input (pin 5) of the second half of the op amp, IC2b. Due to the limited current applied to ZD1, the peak voltage is around 6.5V.



Scope5: the yellow trace shows the Supply's output voltage, and the green trace shows its current delivery, at around 2.5A/div. It's delivering 4A at 24V into a 6Ω load but the load impedance then suddenly drops to 3.5Ω, increasing the current to nearly 7A. The current limit has been set to around 5A, so the supply reacts within a few milliseconds to reduce the output voltage. The load current settles at the set value around 10ms later.



Scope6: this shows a 4A resistive load being connected to the Supply while it is delivering 25V. The output is never more than 200mV from the setpoint and settles in much less than 1ms. A load with any amount of capacitance will see even less deviation than this.

The 10kΩ NTC thermistor is connected in series with a 9.1kΩ resistor, to form a voltage divider across the 12V rail. The thermistor is connected at the bottom of the divider, so that as its temperature rises, the voltage at the divider junction decreases.

At 20°C, the voltage is around 7V, dropping to around 2V at 60°C. This voltage is fed into IC2's pin 6, the inverting input. When the truncated triangle waveform voltage is above the thermistor voltage, output pin goes high and when the triangle voltage is below the thermistor voltage, that output is low.

Thus pin 7 of IC2b produces a square wave at 280Hz with a duty cycle that increases as the thermistor temperature increases. This drives the gate of N-channel Mosfet Q10 (IRF540) via a 1kΩ resistor, which powers the two fans. A 10kΩ pull-down on the Mosfet gate ensures it switches off when power is removed.

We have two 24V DC fans wired in series and connected via CON4 and CON5. When Q10 is on, about 9V appears across the 33Ω 5W ballast resistor, reducing the ~57V DC supply voltage to around 48-49V so they each run off about 24V. The powerful fans we have chosen draw about 280mA at 24V. If you use different fans, you will need to alter the resistor value to suit.

When the temperature at the thermistor is near ambient, the thermistor divider is at around 7V and is above the 6.5V peak set by the zener diode. Thus output pin of IC2b remains low and Q10, and the fans are off.

When the divider voltage drops below the voltage set by ZD1, the fan quickly jumps up to a duty cycle of approximately 40%. This ensures that the fans start reliably, and is the reason for the presence of ZD1.

The duty cycle increases as the temperature rises until the thermistor divider voltage is below the trough of the triangle waveform, in which case Q10 and the fans are switched on 100% of the time. Thus the fans can dynamically respond to changes in temperature.

Scope1-Scope4 show how the duty cycle varies in response to changes in temperature.

Thermal shutdown

The thermistor voltage is also fed to NPN transistor Q11 via a 100kΩ base resistor and diode D4. This means that Q11 switches off if the thermistor voltage drops below 1.2V.

The high resistor value means that this part of the circuit does not affect the thermistor voltage significantly.

If the thermistor temperature rises above 80°C, the divider voltage drops below 1.2V and Q11 switches off. Its collector voltage rises enough to allow current to flow through D3, charging the following 1µF capacitor.

This eventually provides enough base current for NPN transistors Q12 and Q13 to switch on, lighting LED1 and pulling down the wiper voltage of current set potentiometer VR4.

In practice, the current limit setpoint does not reach exactly zero when this happens, but stabilises at around 100mA, reducing the maximum dissipation in the output devices to below 10W.

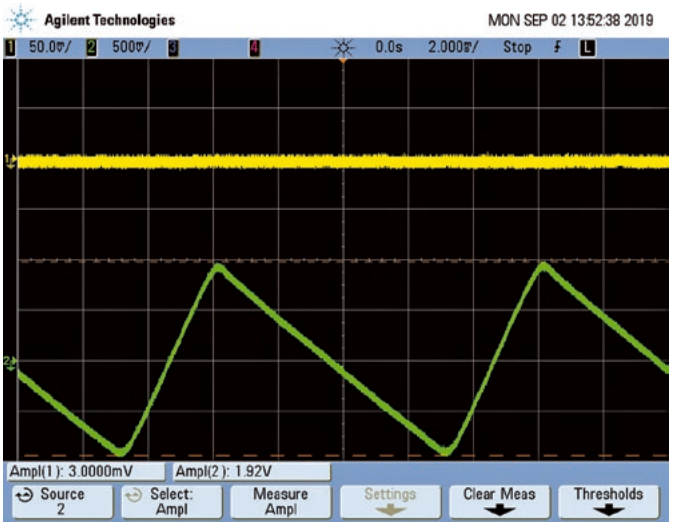
The 1µF capacitor can only discharge via the two 100kΩ base resistors, giving around a one-second delay between the thermistor voltage dropping and the current limit returning to normal.

This, in combination with the thermal mass of the heatsink, prevents the thermal limiting from switching on and off rapidly.

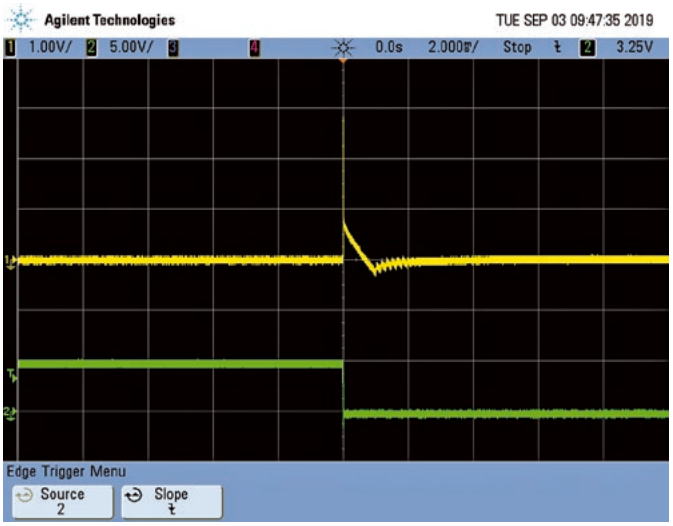
Monitoring voltages and currents

To avoid the need for hooking multiple multimeters up to the Bench Supply to see what it's doing, it incorporates five read-outs. These can be shown on a single LCD screen or multiple panel meters.

Regardless, the Bench Supply board has to provide analog voltages to feed to these displays. These voltages are buffered by dual op amps IC5 and IC6,



Scope7: the green trace shows around 2V of ripple on the pre-regulator 4 x 4700µF capacitor bank with the Supply delivering 4A into 25V. The yellow trace is the Supply's output. The scope measures 3mV of ripple, but this comparable in magnitude to the noise that the scope probes pick up when grounded.



Scope8: This is the reverse of the scenario seen in Scope6, with a 4A resistive load being disconnected from the Supply at 25V. There is around half a volt of overshoot followed by a lesser amount of undershoot and the output settles completely within 2ms.

which are powered from the same +24V and -5V rails as control op amp IC1. They form four unity gain amplifiers. Their non-inverting inputs are connected to TP1, TP2, TP3 and TP4.The output from each buffer is fed into a 10kΩ trimpot (VR5-VR8) to allow you to adjust the voltage scaling to suit the display(s).

These trimpots effectively allow any fraction of the reference voltage to be fed to the panel meters. The thermistor voltage is scaled down by a pair of 1MΩ resistors to provide a 0-5V signal suitable for feeding to a microcontroller.

A 100nF bypass capacitor provides a low-impedance source for whatever is connected to sample it. The time constant of the 1MΩ/100nF low-pass filter is not a problem because the thermistor temperature does not change rapidly.

All the buffered signals are fed to DIL header CON6, along with ground connections and a 5V supply to run the LCD screen or panel meters.

As an example, when the Bench Supply is delivering 50V, there will be 15.6V at TP2. IC5b buffers this, and VR6 can be set so that 5V is fed to pin 5 of CON6 in this condition, ie, one-tenth of the actual output voltage. The panel meter just needs its decimal point set so that it reads 50.0 when receiving a 5V signal.

Similarly, the current values can be displayed on a voltmeter, with the range appropriately set by scaling and placement of the decimal point. A similar scaling by a factor of 10 is appropriate here too.

Five-way Panel Meter

While we don't know of any panel meters that will be able to directly read the thermistor voltage and convert it into a temperature, our microcontroller-based Five-way Panel Meter design can interpret it, as well as displaying the two voltage and two current values.

The details of this low-cost Five-way Panel Meter will be in next month's issue, coinciding with the PCB construction and testing details for the Bench Supply.

If you don't want to use that Panel Meter board, but you want a temperature read-out, you could feed the voltage from pin 11 of CON6 to an analog meter and draw an appropriate scale, calibrated to match the thermistor temperature.

Internal power supply

24V linear regulator REG1 is fed from the 57V rail via a 220Ω 5W dropper (ballast) resistor. This reduces dissipation in the regulator while its 100µF input bypass capacitor prevents that resistor from affecting regulation.

The 24V rail powers the output control op amps (IC1), the sense buffer op amps (IC5 & IC6) and is the reference voltage for the output voltage and current adjustment potentiometers (VR3 & VR4).

The 24V rail also feeds into 12V regulator REG4 via another ballast resistor, this time 68Ω 1W. The 12V supply feeds the negative voltage generator, the current shunt monitor IC, the thermistor and fan control, and the 5V regulator (REG5). The resulting 5V rail is for powering the panel meter/display(s).

The negative voltage generator consists of a 555 timer (IC3) operating in astable mode at around 60kHz, with a near 50% duty cycle. Its output is connected to 1N4148 diodes D1 and D2 via a 100µF capacitor, forming a charge pump.

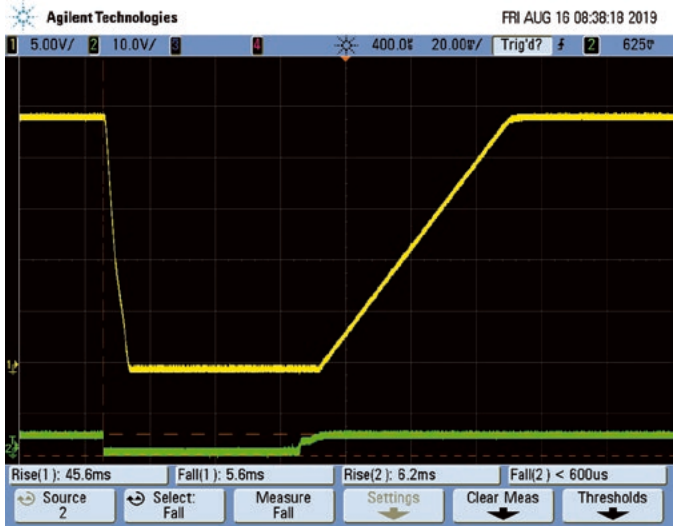
The 100µF capacitor at pin 3 of IC3 charges up through D2 when pin 3 is high. When pin 3 goes low, D2 is reverse-biased and current instead flows through D1, charging up the 100µF capacitor at REG2's input. This results in around -9V at the input of REG2, resulting in a regulated -5V rail at its output.

Heatsinking

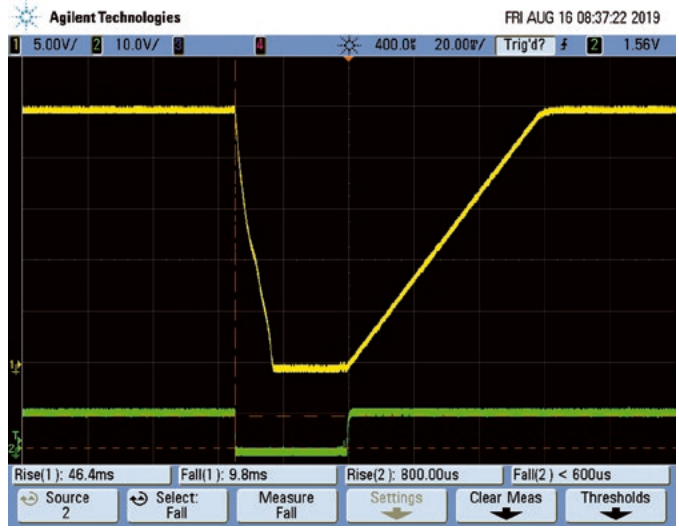
There are three heatsinks in this design, small flag heatsinks for the 12V and 24V regulators (REG4 and REG1) and the main heatsink for REG3, Q3-Q7 and BR1. Due to the high voltages present, regulators REG4 and REG1 have significant dissipation, despite the series ballast resistors which reduce their input voltage.

The 24V regulator is key to setting the voltage and current references, so keeping this device at a uniform temperature will help with the stability of the output.

As mentioned earlier, to efficiently get heat out of transistors Q4-Q7, they are not insulated from the main heatsink


Agilent Technologies
FRI AUG 16 08:38:18 2019
5.00V/ 10.0V/ 400.0ℓ 20.00ℓ/ Trig'd? 625ℓ
Rise(1): 45.6ms Fall(1): 5.6ms Rise(2): 6.2ms Fall(2) < 600us
Source 2 Select: Fall Measure Fall Settings Clear Meas Thresholds

Scope9: here we have simulated a step-change in the voltage control input by shorting the V_{SET} point to ground and then releasing it. The output voltage drop is much quicker than the rise, ensuring that the chance of overshoot is minimised under dynamic conditions.


Agilent Technologies
FRI AUG 16 08:37:22 2019
5.00V/ 10.0V/ 400.0ℓ 20.00ℓ/ Trig'd? 1.56V
Rise(1): 46.4ms Fall(1): 9.8ms Rise(2): 800.00us Fall(2) < 600us
Source 2 Select: Fall Measure Fall Settings Clear Meas Thresholds

Scope10: this current control step-change test shows a similar response as in Scope9. Again, the fall is faster, indicating that the Bench Supply is designed to respond to over-current conditions quickly. There is no visible overshoot.

and it is therefore at around +57V DC potential. 57V DC is considered 'low voltage', but of course there are also mains voltage present around the transformer, so it doesn't hurt to use caution while working on the supply when it's powered.

The LM317HV regulator has a live tab connected to its output, which can vary anywhere between 0V and near the DC rail voltage, so it must be insulated from the main heatsink. We used a silicone pad and an insulating bush.

Similarly, the tab of Q3 is connected to its collector. If the collector were connected to the DC rail, then the output transistors would turn on hard, so this must be avoided. It too is mounted with a silicone pad and insulated bush.

We have purposefully mounted Q3 reversed on the PCB, with its pin 3 on the left, so that its metal tab faces away from the heatsink. That's because, despite an insulating washer, we found it was still shorting to the heatsink via the screw.

Reversing the device solved that. Its dissipation is not that high, so the added thermal resistance is not a big problem. Of course, the thermistor is also mounted on the heatsink and must be insulated too. We used a stud-type thermistor which has the active element potted, so that is already taken care of.

Performance

Scope grabs Scope5-10 demonstrate some of the performance characteristics of the Supply. These grabs demonstrate the effects of sudden 'step' changes in the operating conditions. In reality, most changes won't occur so suddenly.

Importantly, the Bench Supply can respond quickly to changes in load without excessive overshoots, including switching into current limiting when necessary. The scope grabs demonstrate that it typically responds within milliseconds to these sort of changes. See the details of the individual tests underneath the scope grabs.

We also did some thermal tests to determine how well the Bench Supply handles heat dissipation. As noted in our panel about "The Thermal Equation", the Bench Supply works hardest when the output voltage is low, but the current is high. In these cases, the full supply voltage appears across the output transistors.

For example, dumping 8A into a short circuit means that the Bench Supply is delivering around 400W into the heatsink. During our scope grab tests, at 25V and 4A, it is dissipating around 100W.

Under the latter condition, the thermistor registers around 20°C above ambient, and the fans run at around half speed.

One of our more severe tests involved connecting a 2Ω dummy load. With the output set to 8A, the voltage reaches 16V, and the Supply is dissipating around 300W. Under these conditions, the thermistor reached 77°C (around 55°C above ambient) after around 10 minutes and then held steady.

Contrary to what you might think, delivering 45V at 8A is not that stressful to the supply, as there is only about 10V across the output devices and thus a dissipation of around 80W.

Delivering 8A into a short circuit is more difficult; the supply can manage for this, but only for a few minutes at a time before it enters thermal current limiting. SC

NEXT MONTH:

As promised earlier in this article, our November issue will commence the full construction details, including the parts list. If you want to be sure not to miss that issue, why not subscribe to SILICON CHIP? (See page 97).

SILICON CHIP BACK ISSUES

First the good news:

Did you know . . . that back issues of SILICON CHIP magazine are still available, with only a few exceptions, for the **LAST TWENTY YEARS +?**

Check out the following list to see if the issue you want is still in stock.

Order any of these issues online or by phone for just $13.00 INCLUDING p&p in Australia!

See the website address below or call (02) 9939 3295 9-4, Mon-Fri

1997: all except August & September
1998: all except March
1999: all except February
2000: all except April
2001: all except October & December
2002: all except June & July
2003-2005: all available
2006: all except January & October
2007-2010: all available
2011: all except November & December
2012: all except December
2013: all except February
2014: all except January
2015: all except January
2016-2019: all available

And the even better news:

Did you know . . . that if the issue you want is out of stock, we can supply a copy of any article from any issue (nominate which article you require. Price is the same as a back issue due to the extra work required).

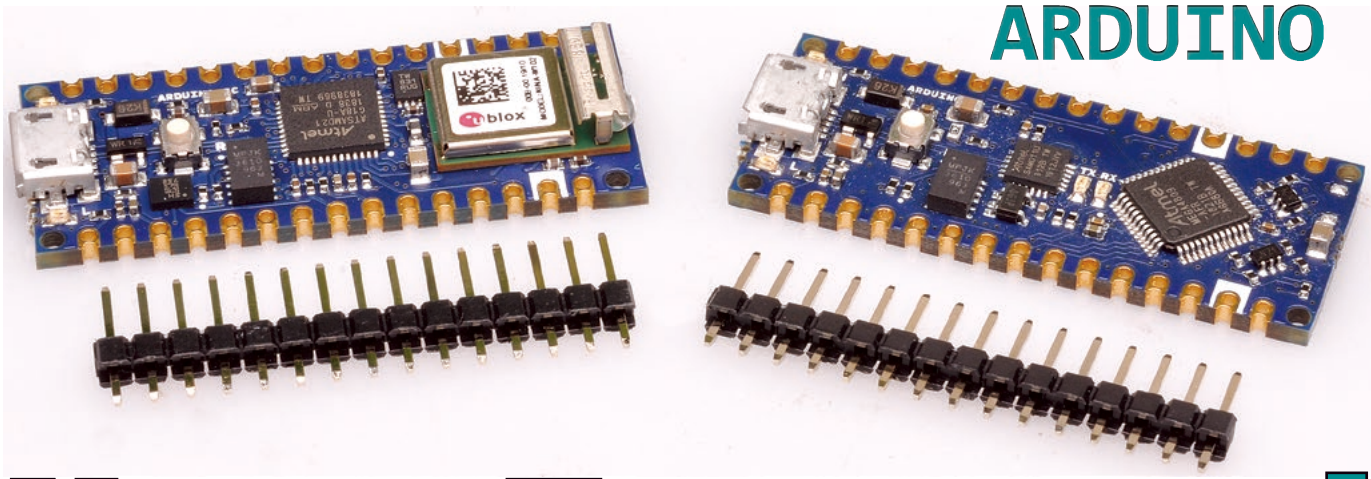
And now the best news:

Did you know . . . that you can also view most articles on the SILICON CHIP website! And if you're a subscriber, (print or online) there's even a discount on the price (as there is with any other SILICON CHIP ONLINE SHOP merchandise).

Log on today for all the details:

www.siliconchip.com.au

NEW FROM ARDUINO



Nano Every and Nano 33 IoT

Several new Arduino Nano boards were recently released. We got a hold of the two most interesting new boards, the Nano Every and Nano 33 IoT, to see what's new, figure out how to use them and get an idea of what they're good for.

The Arduino company has added four new Nano boards to their range. These use the same compact and breadboard-friendly form factor as the original Nano, but with a lot of extra performance and features.

To program these, you will need to be familiar with the Arduino software environment, specifically, their Integrated Development Environment (IDE) which can be downloaded for free from: siliconchip.com.au/link/aatq

The Nano Every

The first board we will look at is called the "Nano Every". Instead of using the ATmega328 processor used in the Arduino Uno, Duemilanove and Nano (among others), it has the much newer ATmega4809 micro.

This board is an upgraded drop-in substitute for the older Nano. The pin layout is the same and its I/O pins work at 5V levels, in contrast to many other recent Arduino boards which have 3.3V I/O levels.

One example of a 3.3V Arduino is the Arduino MKR Vidor 4000 which we reviewed in March this year (siliconchip.com.au/Article/11448).

The Nano 33 IoT

The second board we're reviewing is the Arduino Nano 33 IoT. The "33" emphasises the fact that this board has 3.3V I/O levels.

It is based on a SAMD21G18A (ARM Cortex M0+) processor and has the same NINA W102 WiFi module as the Vidor board mentioned earlier. The WiFi features are the reason for the "IoT" (Internet of Things) designation, as you need network connectivity for that.

The two other boards released at the same time as these are the Nano 33 BLE and Nano 33 BLE Sense. Both are based on a NINA B306 module, which provides support for Bluetooth.

The difference between the two is that the Sense version boasts several extra sensors; these add up to make it the most expensive Nano series board.

We haven't bothered reviewing those two because we think that the WiFi version is more generally useful, while also being cheaper.

Review by Tim Blythman

Price

Speaking of price, these new Nano boards are inexpensive. From the of-

ficial Arduino store (at https://store.arduino.cc/usa/nano-family), the Nano Every is less than half the price of even the original Nano, coming in at US$9.90 (approx AU$14.50 at press time). The Nano 33 IoT is just US$18.00 (approx AU$26.90), even less than an R3 Arduino Uno board.

The headers are included separately with both packs, and we had no hesitation in saving ourselves the $2 or so that it would have cost us to have them fitted at the factory.

Nano Every details

The "Getting Started" page at www.arduino.cc/en/Guide/NANOEvery notes that the Nano Every is fully compatible with the original Nano.

Table 1 shows a comparison between the specifications of the ATmega4809 micro (as used in the Nano Every and the Uno WiFi Rev2 board) and the good old ATmega328.

We've also included the SAMD21G18A in this comparison, as used in the Nano 33 IoT.

Note though that the Nanos, as supplied, can't necessarily use all of their theoretical capabilities.

For example, the Nano Every runs at 16MHz, despite the chip being capable of 20MHz (it's even listed on the Every's product page as 20MHz). The reason is that it has a 16MHz crystal onboard.

Also, the original Nano only had 30kB available for user programs, as 2kB of the chip's memory is reserved for the bootloader.

The Nano Every does not use a bootloader, but instead is directly programmed by a second chip on the board, so the full 48kB is available.

The extra flash (+50%) and RAM (+200%) on the Every are welcome improvements. RAM is especially tight on the ATmega328-based Arduinos.

We doubt most users will be inconvenienced by the smaller EEPROM size; generally, you only need to use it to store a few settings.

The ATmega4809 can write to its own flash, so you can allocate some of that as non-volatile storage, although the Arduino framework doesn't provide an easy way to do this (and it doesn't have anywhere near the endurance or convenience of a proper EEPROM).

As shown in Table 1, the ATmega4809 is programmed via UPDI (Unified Program and Debug Interface).

	ATmega328	ATmega4809	SAMD21G18A
Flash Memory	32kB	48kB	256kB
SRAM	2kB	6kB	32kB
EEPROM	1024B	256B	0B
Programming method	ICSP	UPDI	Bootloader
Max clock speed	20MHz	20MHz	48MHz
SPI/UART/I²C interfaces	3	6	3
ADC pins	8 (6 in DIP)	16	7

Table 1 - Arduino Nano micros comparison

We've seen UPDI previously on the ATtiny816, which we reviewed in January 2019 (siliconchip.com.au/Article/11372).

UPDI only requires one extra pin apart from power and ground connections, and this is usually shared with the RESET pin, meaning that no I/O pins are lost.

The second chip on the Nano Every is a very capable ARM-based ATSAMD11D14A. It programs the ATmega4809 via UPDI, and it also acts as the USB-Serial bridge (much like the Microbridge chip in the Micromite BackPack V2/V3 and recent Explore-28).

Six pads on the back of the board are connected to the ATSAMD11D14A and can be used to update its firmware, should that become necessary.

The USB interface is provided via a micro-USB socket, as is common on mobile phones.

Also on the Nano Every board is an MPM3610 regulator, providing a regulated 5V rail from the VIN pin.

This IC is a switchmode device which can deliver up to 1.2A from input voltages up to 21V.

This is a major improvement from previous Arduinos, so now the 5V rail can supply high currents to connected peripherals without the regulator overheating. Watch out for Clones of the Nano Every as they may revert to an inferior linear regulator to reduce the cost!

There's also a 3.3V regulator to power the ATSAMD11D14A and three level shifting transistors for the TX, RX and UPDI lines. These are rounded out with two LEDs (for power and digital pin 13 activity), a reset button and the usual passives like bypass capacitors.

The I/O pin mounting pads have castellated edges, making it possible to surface-mount the board on another PCB instead of soldering on headers.

It has been suggested that it could be possible to add features to this board by reprogramming the ATSAMD11D14A bridge chip. However, the extra ATmega16u2 chip on Uno boards was also capable of this, yet such mods were never particularly popular.

As of writing this article, a minor bug exists in the USB-Serial bridge firmware of early releases of the boards which can cause it to lock up when receiving more than 128 bytes from the serial port.

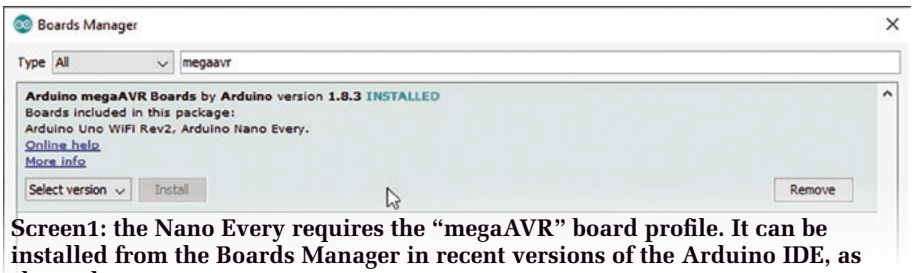
New boards will have this bug fixed, but there are already quite a few in circulation with that problem.

The firmware can be updated by using the "bossac" program, which is installed with SAMD board profiles under the Arduino IDE.

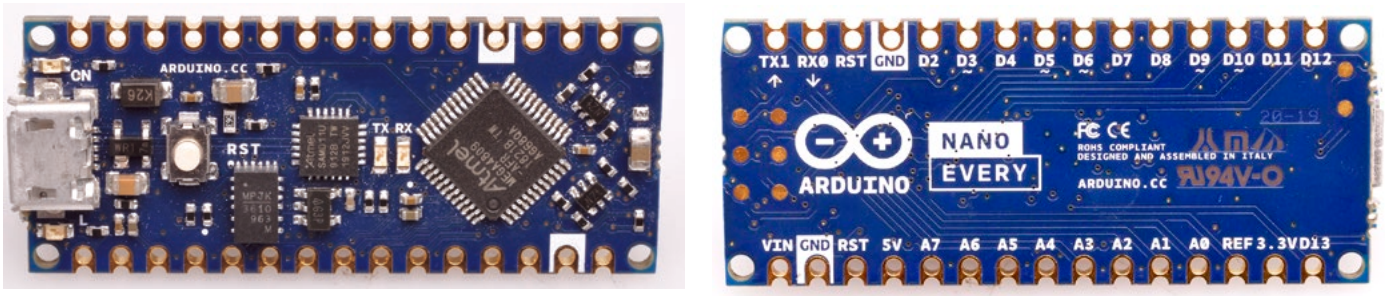
Nonetheless, this is still an inconvenience which could cause some frustration for inexperienced users (at which Arduino is firmly aimed).

Using the Nano Every

The ATmega4809 processor on the Every has some newer features that have been added to the AVR family since Microchip's takeover of Atmel in 2016.



Screen1: the Nano Every requires the "megaAVR" board profile. It can be installed from the Boards Manager in recent versions of the Arduino IDE, as shown here.


ARDUINO.CC
RST
TX RX
TX1 RX0 RST GND D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12
ARDUINO
NANO
EVERY
ARDUINO.CC
VIN GND RST 5V A7 A6 A5 A4 A3 A2 A1 A0 REF 3.3V D13

Like many Arduino boards, the hardware designs are available for download, although the Nano Every would be harder to build than the older through-hole boards. The back of the PCB is empty, allowing it to be mounted flat on a PCB using the castellated pads along its edges. These photos are shown about twice life size for clarity. (Actual size of the Arduino Nano Every is 43 x 18.5mm)

These include custom-configurable logic (CCL), programmable look-up tables (LUT), a peripheral Event System and more. However, there are not many libraries presently available to take advantage of these new features.

The so-called "megaavr" software core needs to be installed in the Arduino IDE to use the Every. It can be installed from newer (1.6.4 or later) versions of the IDE by using the Boards Manager and searching for "megaavr". Screen1 shows the result of this search. Make sure you use megaavr version 1.8.3 or later as earlier versions had some bugs.

Once installed, the board can be selected from the Arduino megaAVR boards group under the Tools menu. We compiled and uploading the "Blink" sketch to test that everything worked as expected. This resulted in a sketch size of 1370 bytes, and the upload took a few seconds. There was an error message "Cannot locate 'flash' and 'boot' memories in description", but it worked despite that.

Interestingly, the "Blink" sketch compiled for the original Nano comes to around 930 bytes; even a blank sketch compiles around 400 bytes larger on the Every than the original Nano. This is due to the extra initialisation code that the Arduino IDE tacks on. It's a minor loss compared to the extra 16kB of flash on the chip.

	Nano Every	Original Nano	Nano 33 IoT
digitalRead	6.679µs	5.032µs	0.984µs
digitalWrite	6.459µs	4.532µs	1.913µs
pinMode	3.244µs	4.470µs	1.931µs
multiply byte	0.570µs	0.632µs	0.197µs
divide byte	5.297µs	5.412µs	0.636µs
add byte	0.381µs	0.443µs	0.197µs
multiply integer	1.263µs	1.386µs	0.171µs
divide integer	14.052µs	14.277µs	0.591us
add integer	0.759µs	0.883µs	0.171µs
multiply long	5.547µs	6.102µs	0.168µs
divide long	38.362µs	38.662µs	0.596µs
add long	1.514µs	1.763µs	0.169µs
multiply float	7.314µs	7.932µs	3.016µs
divide float	78.337µs	80.162µs	11.721µs
add float	9.692µs	10.107µs	2.806µs
itoa()	12.792µs	12.597µs	3.041µs
ltoa()	125.487µs	125.987µs	16.196µs
dtostrf()	76.687µs	78.637µs	
random()	90.512µs	91.412µs	9.546µs
y |= (1<<x)	0.444µs	0.569µs	
bitSet ()	0.444µs	0.569µs	0.123µs
analogRead()	112.887µs	111.987µs	422.946µs
analogWrite() PWM	6.932µs	7.167µs	6.801µs

Table 2 - Nano board performance comparison (lower is better)

Occasionally, we found that the Every stalled during the upload process. Because sketch uploading requires the transfer of much data over the serial port, we suspect this is related to the bug noted earlier.

We found a benchmarking test sketch online at: http://siliconchip.com.au/link/aau5 We compared the Nano Every against the original Nano using it.

On the original Nano, the sketch compiled to 20722 bytes, while the Every needed 21600 bytes, almost 1kB more. Otherwise, the performance is quite similar, and there's nothing significant enough to favour one over the other speed-wise (see Table 2).

There is an option in the tools menu of the IDE to change the "Register Emulation" to suit either the ATmega328 or ATmega4809.

It appears this is part of Arduino's pitch that the Every is compatible with the original Nano. We saw no effect from changing this option. The "Getting Started" page mentions that this option may help with sketches that contain assembly language or do not manage pin mapping.

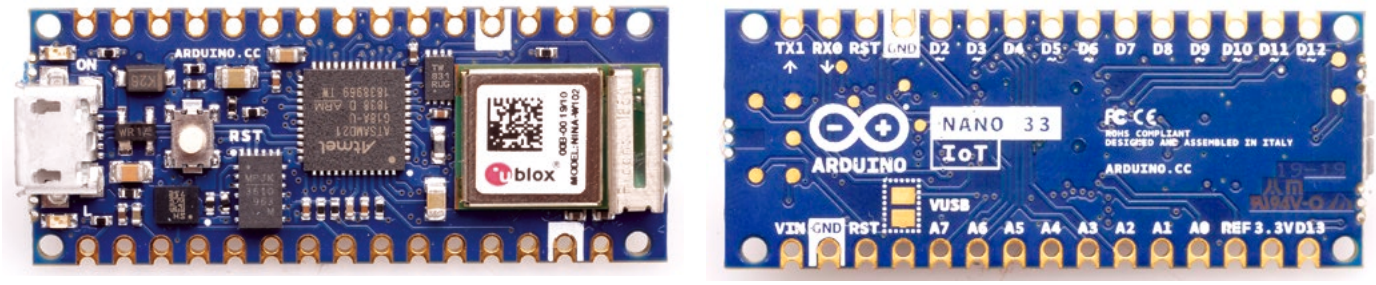
We found that some sketches using direct port writes would not compile for the Every, even though they did compile for the Uno WiFi Rev2 (which has the same microcontroller).

Most users would not run into this problem, but it suggests that some third-party libraries will not work on the Nano Every.

Interestingly, there is one less PWM channel available on the Every than on the original Nano. Pin 11 can no longer be used for PWM, so sketches that depend on this feature are also not compatible with the newer board.

Is it Every-thing we hoped for?

Probably the biggest advantage of



The Nano 33 IoT is packed with components; the NINAW102 WiFi module is easily the largest. The slotted metal piece at far right is the 2.4GHz antenna. It's unfortunate that the only space for pin markings is on the back of the package. If you don't need access to the reset button and status LEDs, the headers could be mounted on the opposite side, to allow the markings to be seen while the Nano is plugged into a breadboard. Again, these are shown about twice life size.

the Every is its price. Given that it's cheaper than the genuine original Nano and has more flash and RAM, unless you absolutely need compatibility with the original Uno/Nano, you might as well use the Every instead. It is one of the handiest 5V-based Arduino boards available.

Like some of the newer PIC microcontrollers, the ATmega4809 offers peripheral pin select, meaning its internal peripherals can be re-mapped to different pins. It also offers CCL (configurable custom logic) which allows simple logic functions to be performed in hardware on the input and output signals.

An example would be gating a clock signal with an AND gate or inverting a signal with a NOT gate.

These features are a bit beyond the scope of the intended Arduino audience, but advanced users can experiment with them by diving deep into the data sheet and tweaking the internal registers directly.

These features will allow the Every to be much more efficient at certain tasks than the original Nano.

Interestingly, since Microchip's MPLAB X IDE supports the ATmega4809, you could program it using that software instead, using pure C/C++ rather than the modified version of C++ used in the Arduino IDE.

Nano 33 IoT details

The Nano 33 IoT has the same footprint as the other Nano boards. Like the Every, if it is ordered without headers attached, it can be surface-mounted on another PCB as if it were a component.

The SAMD21G18A processor is common to many of the newer 32-bit Arduino boards, including the Vidor board that we reviewed previously. This is a very different architecture to AVR-based boards.

So it is even less likely than the Every to be compatible with existing Nano projects. It does, however, maintain the six PWM outputs in familiar locations and adds a seventh PWM output at digital pin 2.

Like other SAMD based boards, though, it is only compatible with 3.3V I/O levels.

The Nano 33 IoT is very similar to the Vidor in many aspects. WiFi is provided by the same NINA W102 module (which contains an ESP32 running custom firmware) and it also has an ATECC608A crypto chip, similar to the ATECC508A on the Vidor. The Nano 33 IoT is also similar to the larger MKR WiFi 1010 board.

The crypto chip is used for encrypting WiFi and internet communications. There is also an onboard LSM6DS3 IMU (inertial measurement unit) which connects to the main processor via an I^2C bus. The IMU can be used to detect the orientation and rotation of the board.

There is no separate serial-USB converter, as the SAMD21G18A has its own USB interface which provides a virtual serial port.

Otherwise, the board is similar to the Every. An MPM3610 switchmode regulator provides the 3.3V rail. A 5V rail is only available directly from the USB port and if a solder jumper is closed. The power and pin D13 LEDs, a reset button and a handful of passives complete the board.

We didn't find any bugs affecting the Nano 33 IoT, probably because it is so similar to other MKR series boards such as the Vidor which have been around for a while.

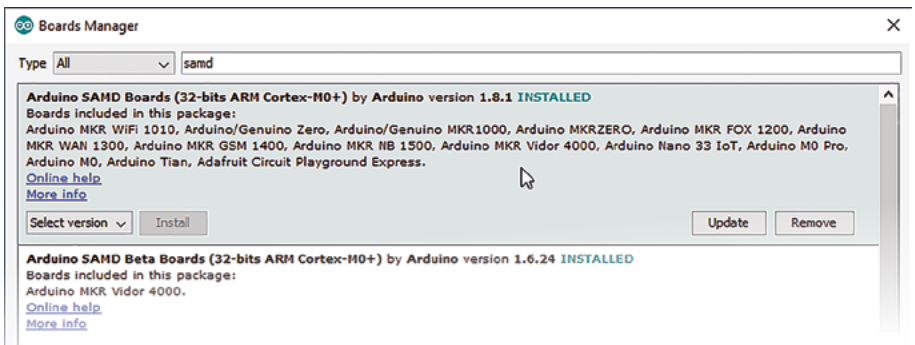
Using the Nano 33 IoT

The Nano 33 IoT can also be added to the Arduino IDE through the Boards Manager. See Screen2 for the correct board profile to install; we recommend searching for "samd" although it brings up more than one result. The option including the Nano 33 IoT name is correct. Click on the item then click the button to install it.

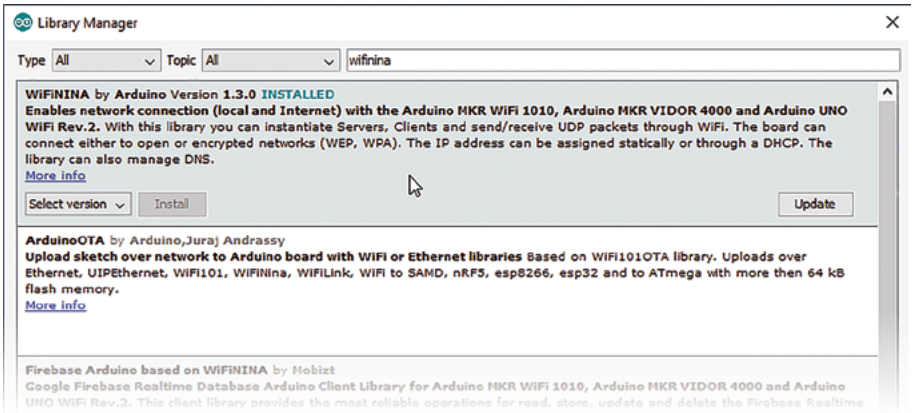
Note that the Vidor board had its own separate "SAMD beta" board profile, but these have now been merged into one.

Again, We tried the "Blink" sketch, and everything worked as expected. We then tried the same benchmarking program as before.

We had to delete some of the tests as it appears that the functions they use are not defined under the SAMD board profile. Although a minor


Boards Manager
Type All
samd
Arduino SAMD Boards (32-bits ARM Cortex-M0+) by Arduino version 1.8.1 INSTALLED
Boards included in this package:
Arduino MKR WiFi 1010, Arduino/Genuino Zero, Arduino/Genuino MKR1000, Arduino MKRZERO, Arduino MKR FOX 1200, Arduino MKR WAN 1300, Arduino MKR GSM 1400, Arduino MKR NB 1500, Arduino MKR Vidor 4000, Arduino Nano 33 IoT, Arduino M0 Pro, Arduino M0, Arduino Tian, Adafruit Circuit Playground Express.
Online help
More info
Select version
Install
Update
Remove
Arduino SAMD Beta Boards (32-bits ARM Cortex-M0+) by Arduino version 1.6.24 INSTALLED
Boards included in this package:
Arduino MKR Vidor 4000.
Online help
More info

Screen2: the Nano 33 IoT requires the "SAMD" board profile, which also supports many other recent Arduino boards, including the Vidor and other MKR series boards.


Library Manager
Type All
Topic All
wifinina
WiFiNINA by Arduino Version 1.3.0 INSTALLED
Enables network connection (local and Internet) with the Arduino MKR WiFi 1010, Arduino MKR VIDOR 4000 and Arduino UNO WiFi Rev.2. With this library you can instantiate Servers, Clients and send/receive UDP packets through WiFi. The board can connect either to open or encrypted networks (WEP, WPA). The IP address can be assigned statically or through a DHCP. The library can also manage DNS.
More info
Select version
Install
Update
ArduinoOTA by Arduino,Juraj Andrassy
Upload sketch over network to Arduino board with WiFi or Ethernet libraries Based on WiFi101OTA library. Uploads over Ethernet, UIPEthernet, WiFi101, WiFiNina, WiFiLink, WiFi to SAMD, nRF5, esp8266, esp32 and to ATmega with more then 64 kB flash memory.
More info
Firebase Arduino based on WiFiNINA by Mobizt
Google Firebase Realtime Database Arduino Client Library for Arduino MKR WiFi 1010, Arduino MKR VIDOR 4000 and Arduino

Screen3: the "WiFiNINA" library is required to use the WiFi module on the Nano 33 IoT. This library also interfaces with the onboard crypto chip.

problem, that indicates a lack of total compatibility.

The compiled code was around 33kB, larger again than for either of the other Nanos. This is not unexpected as the Nano 33 IoT has a 32-bit processor compared to the other boards' 8-bit processors. You can see the results in Table 2. Those which we could not run appear as blank rows.

It is substantially faster in almost every test. The one outlier is the analogRead(), which is much slower on the Nano 33 IoT, presumably due to a longer analog sampling time.

We also scanned the I^2C bus to detect the onboard devices. The IMU IC is at address 0x6A, which matches the address in the LSM6DS3 datasheet with its SA0 pin tied low.

The crypto chip was not listed, but if it is like the Vidor, the address will be 0x60.

To make use of the WiFi module, you need the "WiFiNINA" library. This can be installed through the Library Manager (accessible from the Sketch → Include Library → Manage Libraries… menu option) by searching for "wifinina" search term.

See Screen3 for details; it is the topmost library.

The library also includes some sample code, found under the File → Examples → WiFiNINA menu. We tested the ability of the board to use encryption with the "WiFiSSLClient" example sketch.

This requires the SSID and password of an internet-connected WiFi network to be added, after which the sketch connects to a Google server using HTTPS (port 443) and performs a search with the query term "arduino". The retrieved text can then be displayed (after copying and saving) as a web page.

There's an old joke which says that the "S" in "IoT" is for security. So it's refreshing to find that this IoT board makes it so easy to connect and communicate using secure protocols.

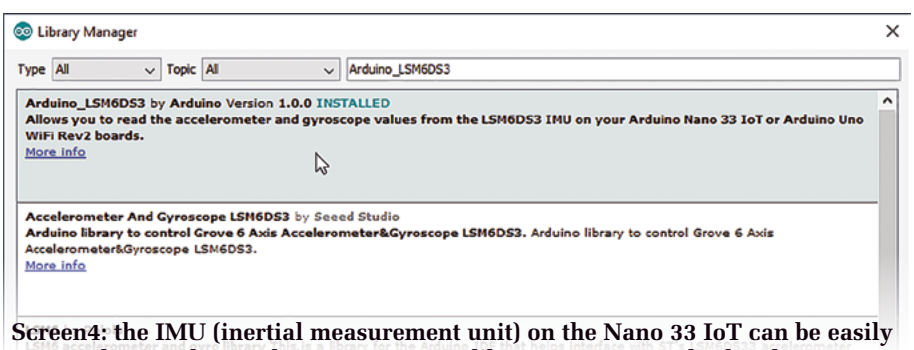
You also need a library to use the onboard IMU. The recommended one is called "Arduino_LSM6DS3" and can be found by searching for its name in the Library Manager, as shown in Screen4.

Two example sketches show how to read the orientation and rotation from the sensor.

Another great feature of the SAMD-21G18A is that it can operate as both a USB device and a USB host, meaning you can connect devices like a USB flash drive to it. Libraries to support these features are included with the board profile.

With features such as WiFi, USB and onboard sensors, the chances of this board having everything you need already present are quite good.

We were able to run all our tests without even having to solder the header pins. Size becomes the predominant factor.


Library Manager
Type All
Topic All
Arduino_LSM6DS3
Arduino_LSM6DS3 by Arduino Version 1.0.0 INSTALLED
Allows you to read the accelerometer and gyroscope values from the LSM6DS3 IMU on your Arduino Nano 33 IoT or Arduino Uno WiFi Rev2 boards.
More info
Accelerometer And Gyroscope LSM6DS3 by Seeed Studio
Arduino library to control Grove 6 Axis Accelerometer&Gyroscope LSM6DS3. Arduino library to control Grove 6 Axis Accelerometer&Gyroscope LSM6DS3.
More info

Screen4: the IMU (inertial measurement unit) on the Nano 33 IoT can be easily accessed using the "Arduino_LSM6DS3" library. Two example sketches are included.

The verdict

The Nano 33 IoT packs a lot into a small size.

It's a radical departure from the original Nano and is not in the same league: it's pretty much better in every way (unless you need 5V I/Os) and despite this, is cheaper than a genuine original Nano.

Really, the only Nano feature that's left is the footprint!

We think this board will be very popular. The ability to work as a USB device such as a keyboard means we may see the Arduino Micro board being replaced as the default choice for applications that require it.

The minimum regulator input voltage of 4.5V means that it cannot run from a Li-ion or LiPo cell, but that is a minor quibble.

However, larger boards such as the MKR range can run from a lithium rechargeable battery and provide the required charge and regulator functions.

Along with the Every, the ability to use the board as surface-mounted components is helpful as it means you can test your design on a breadboard, then easily mount them on a larger PCB in the final application.

Where to get them

As well as the Arduino online store (https://store.arduino.cc/usa/arduino-nano), they are starting to appear at other retailers, including:

Digikey: siliconchip.com.au/link/aav0

Mouser: siliconchip.com.au/link/aav2

Core Electronics: siliconchip.com.au/link/aav1

Digi-key and Mouser both offer free express international delivery for orders over AU$60, so if you order a few Nanos (or one or two Nanos plus some other parts), you won't have to pay for postage. SC

PRODUCT SHOWCASE

Prototyping that Fits!

Copper Clad Design Co's line of proto-boards allows projects to directly fit in an enclosure, no glue or hassle, saving time and giving a more professional appearance.

These proto-boards boast a new hybrid of 'strip' and 'dot board' prototyping methods resulting in fewer cut traces, greater ease in connections or opting traces into power rails.

Greater accessibility to power rails coupled with opt-in traces lessens the number of wire links needed. These benefits in time savings and in ease of project assembly help all makers from beginners to students and professionals.

Each proto-board suits a large range of enclosures and components; Arduinos, Raspberry Pis, various modules, etc.

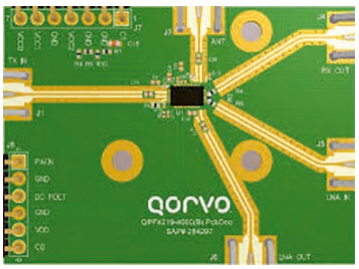
Time is money, and our designs give that back along with

the peace of mind that things just fit!

Give it a try: currently available from Bendigo Electronics (bendigoelectronics.com.au) and Horsham Electronics (Ph. 03 5382 4150).

Contact:
Copper Clad Design Co.
email: sales@coppercladdesignco.com

Qorvo QPF4219 Front End Module for IoT WiFi 5

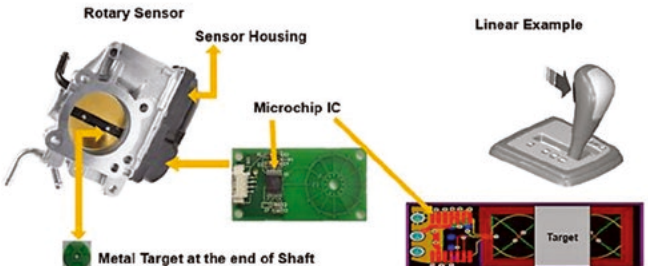


Mouser Electronics, Inc is now stocking the QPF4219 front end module (FEM) from Qorvo. Designed for Internet of Things (IoT) systems based on Wi-Fi 5 (802.11ac), the 2.4GHz FEM offers a compact form factor and integrated matching to minimise layout area in applications such as wireless routers, residential gateways, and access points.

Qorvo's QPF4219 FEM integrates a 2.4 GHz power amplifier (PA), regulator, single-pole double-throw (SPDT) switch, low noise amplifier (LNA) with bypass mode, and voltage power detector into a single device. The device focuses performance on optimizing the PA for a 5V supply voltage by conserving power consumption while maintaining the highest linear output power and exceptional throughput.

Contact:
Mouser Electronics
2 Wing Yip St, Kwun Tong, Kowloon, HK.
Tel: 0011 (852) 3756 4700
Website: au.mouser.com

Inductive sensors replace Hall effect devices



Offering significant advantages over existing Hall effect and other magnetic sensors, our sensor interface ICs measure linear, angular/rotation, proximity and/or displacement in electromechanical systems found in a variety of automotive, industrial, aerospace and commercial applications.

They are excellent solutions for high-reliability and safety-critical automotive position sensor applications, such as automobile throttle body, transmission gear sensing, electronic power steering and accelerator pedals.

These unique magnetic field sensors give accurate position measurements, are immune to stray magnetic fields and don't require an external magnetic device.

Contact:
Microchip Technology Australia
Tel: (02) 9868 6733
Web: www.microchip.com

New Website will tell you . . . How Scams Work!

Scams remain a billion dollar business because people keep falling for them. Malicious internet users are increasingly exploiting social networks, SMSs, registration, subscription and feedback forms on websites to insert spam content or phishing links.

A newly-founded website called How Scams Work has four built-in scam simulators, including an email, SMS, and two phishing scam simulators.

These simulators are designed to help people understand in detail what to do when they encounter a scam.

Each simulator uses identical teachings and methods that security writers speak and talk about regularly but with a more direct and interactive way.

Leading cybersecurity firm Kaspersky is working with How Scams Work to help promote this newly created site. In a recent analysis from Kaspersky, after Brazil, Australia had the second largest share of users attacked by phishers (with 17.20%).

Attackers will continue to use social networks to achieve their goals which calls for more vigilant choices to be made by consumers when it concerns their safety online. SC

Contact:
How Scams Work
Website: www.howscamswork.com.au

SILICON CHIP .com.au/shop ONLINESHOP

Looking for a specialised component to build that latest and greatest Silicon Chip project? Maybe it's the PCB you're after? Or a pre-programmed micro? Or some other hard-to-get "bit"? The chances are they are available direct from the Silicon Chip Online Shop.

- **PCBs are normally IN STOCK and ready for despatch when that month's magazine goes on sale (you don't have to wait for them to be made!).**
- **Even if stock runs out (eg, for high demand), in most cases there will be no longer than a two-week wait.**
- **One low p&p charge: $10 per order, irregardless of how many items you order! (AUS only; overseas clients – check the website for a postage quote).**
- **Our PCBs are beautifully made, very high quality fibreglass boards with pre-tinned tracks, silk screen overlays and where applicable, solder masks.**
- **Best of all, subscribers receive a 10% discount on purchases! (Excluding subscription renewals and postage costs)**

HOW TO ORDER:

VISA MasterCard PayPal

✔ **INTERNET (24 hours, 7 days): log on to our secure website – siliconchip.com.au, click on "SHOP" and follow the links**

✔ **EMAIL – email silicon@siliconchip.com.au – Clearly tell us what you want and include your contact and credit card details**

✔ **MAIL – PO Box 139, Collaroy NSW 2097. Clearly tell us what you want and include your contact and credit card details**

✔ **PHONE (9am-5pm AET, Mon-Fri): Call (02) 9939 3295 (INT +612 9939 3295) – have your order ready, including contact and payment details!**

YES! You can also order or renew your Silicon Chip subscription via any of these methods as well!

PRE-PROGRAMMED MICROS

Micros cost from $10.00 to $20.00 each + $10 p&p per order#

$10 MICROS

ATtiny816	ATtiny816 Development/Breakout Board (Jan19)
PIC12F202-E/OT	Ultrabrite LED Driver (with free TC6502P095VCT IC, Sept19)
PIC12F617-I/P	Temperature Switch Mk2 (June18), Recurring Event Reminder (Jul18) Door Alarm (Aug18), Steam Whistle (Sept18) White Noise (Sept/Nov18) Remote Control Dimmer (Feb19), Steering Wheel Control IR Adaptor (Jun19) Car Radio Dimmer Adaptor / Voltage Interceptor (Aug19)
PIC12F675-I/P	IR-to-UHF Converter (Jul13), UHF-to-IR Converter (Jul13) PC Birdies *2 chips – $15 pair* (Aug13), Driveway Monitor Receiver (July15) Hotel Safe Alarm (Jun16), 50A Battery Charger Controller (Nov16) Kelvin the Cricket (Oct17), Triac-based Mains Motor Speed Controller (Mar18) Heater Controller (Apr18), Useless Box IC3 (Dec18)
PIC12F675-E/P	Courtesy LED Light Delay for Cars (Oct14), Fan Speed Controller (Jan18)
PIC16F1455-I/P	Microbridge & BackPack V2 / V3 (May17 / Aug19), USB Flexitimer (June18) Digital Interface Module (Nov18), GPS Speedo/Clock/Volume Control (Jun19)
PIC16F88-E/P	Auto Headlight Controller (Oct13), 10A 230V Motor Speed Controller (Feb14) Automotive Sensor Modifier (Dec16)
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11) Quizzical (Oct11), Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13) Nicad/NiMH Burp Charger (Mar14), Remote Mains Timer (Nov14) Driveway Monitor Transmitter (July15), Fingerprint Scanner (Nov15) MPPT Lighting Charge Controller (Feb16), 50/60Hz Turntable Driver (May16) Cyclic Pump Timer (Sep16), 60V 40A DC Motor Speed Controller (Jan17) Pool Lap Counter (Mar17), Rapidbrake (Jul17), Deluxe Frequency Switch (May18) Useless Box IC1 (Dec18), Remote-controlled Preamp with Tone Control (Mar19) UHF Repeater (May19), Six Input Audio Selector (TWO VERSIONS, Sept19)
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13), GPS Analog Clock Driver (Feb17)

$15 MICROS

ATmega328P	RF Signal Generator (Jun/Jul19)
PIC16F1459-I/SO	Four-Channel DC Fan & Pump Controller (Dec18)
PIC16F84A-20I/P	Programmable Ignition Timing Module (Jun99), Fuel Mixture Display (Sept00) Oscar Noughts And Crosses (Oct07), UV Lightbox Timer (Nov07)
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun09), 16-bit Digital Pot (Jul10), Semtest (Feb-May12)
PIC32MM0256GPM028-I/SS	Super Digital Sound Effects (Aug18)
PIC32MX170F256D-501P/T	44-pin Micromite Mk2 (Aug14), 4DoF Simulation Seat (Sept19)
PIC32MX170F256B-50I/SP	Micromite Mk2 (Jan15) + ***47µF***, Low Frequency Distortion Analyser (Apr15) Micromite LCD BackPack [either version] (Feb16), GPS Boat Computer (Apr16) Micromite Super Clock (Jul16), Touchscreen Voltage/Current Ref (Oct-Dec16) Micromite LCD BackPack V2 / V3 (May17 / Aug19), Deluxe eFuse (Aug17) Micromite DDS for IF Alignment (Sept17), Tariff Clock (Jul18) GPS-Synched Frequency Reference (Nov18)
PIC32MX270F256B-50I/SP	ASCII Video Terminal (Jul14), USB Mouse & Keyboard Adaptor (Feb19)
PIC32MX795F512H-80I/PT	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12) Touchscreen Audio Recorder (Jun/Jul 14)

$20 MICROS

PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14) Digital Effects Unit (Oct14)
PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Cont. (Oct-Dec10) SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)

$30 MICROS

PIC32MZ2048EFH064-I/PT	DSP Crossover/Equaliser (May19)

SPECIALISED COMPONENTS, HARD-TO-GET BITS, ETC

P&P – $10 Per order#

MICROMITE EXPLORE-28 (CAT SC5121) *(SEPT 19)*
- **Complete kit –** includes PCB plus programmed micros and all other onboard parts **$30.00**
- **Programmed micro bundle –** PIC32MX170F256B-50I/SO + PIC16F1455-I/SL **$20.00**

MICROMITE LCD BACKPACK V3 (CAT SC5082) *(AUG 19)*
- **KIT –** includes PCB, programmed micros, 3.5in touchscreen LCD, laser-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other **mandatory** on-board parts **$75.00**

Separate/Optional Components:
- 3.5-inch TFT LCD touchscreen (Cat SC5062) **$30.00**
- DHT22 temp/humidity sensor (Cat SC4150) **$7.50**
- BMP180 (Cat SC4343) **OR** BMP280 (Cat SC4595) temperature/pressure sensor **$5.00**
- BME280 temperature/pressure/humidity sensor (Cat SC4608) **$10.00**
- DS3231 real-time clock SOIC-16 IC (Cat SC5103) **$3.00**
- 23LC1024 1MB RAM (SOIC-8) (Cat SC5104) **$5.00**
- AT25SF041 512KB flash (SOIC-8) (Cat SC5105) **$1.50**
- 10µF 16V X7R through-hole capacitor (Cat SC5106) **$2.00**

GPS SPEEDO/CLOCK/VOLUME CONTROL *(JUN 19)*
- 1.3-inch 128x64 SSD1306-based blue OLED display module (Cat SC5026) **$15.00**
- laser-cut matte black acrylic case pieces (Cat SC4987) **$10.00**
- MCP4251-502E/P dual-digital potentiometer (Cat SC5052) **$3.00**

TOUCH & IR REMOTE CONTROL DIMMER *(FEB 19)*
- N-channel Mosfets Q1 & Q2 (SIHB15N60E) and two 4.7MΩ 3.5kV resistors (Cat SC4861) **$20.00**
- IRD1 (TSOP4136) and fresnel lens (IML0688) (Cat SC4862) **$10.00**

MOTION SENSING SWITCH (SMD VERSION) *(FEB 19)*
- Short form kit (includes PCB and all parts, except for the extension cable) (Cat SC4851) **$10.00**
- SW-18010P vibration sensor (S1) (Cat SC4852) **$1.00**

DAB+/FM/AM RADIO *(JAN 19)*
- Main PCB with IC1 pre-soldered **$60.00**
- Main PCB with IC1 and surrounding components (white box at top right) pre-soldered **$80.00**
- Explore 100 kit (Cat SC3834; no LCD included) **$69.90**
- Laser-cut clear acrylic case pieces **$20.00**
- Set of extra SMD parts (contains most SMD parts except for the digital audio output) **$30.00**
- Extendable VHF whip antenna with SMA connector: 700mm (**$15.00**) and 465mm (**$10.00**)
- PCB-mounting SMA (**$2.50**), PAL (**$5.00**) and dual-horizontal RCA (**$2.50**) socket

SUPER DIGITAL SOUND EFFECTS KIT (CAT SC4658) *(AUG 18)*
- PCB and all onboard parts (including optional ones) but no SD card, cell or battery holder **$40.00**

USB PORT PROTECTOR COMPLETE KIT (CAT SC4574) *(MAY 18)*
- All parts including the PCB and a length of clear heatshrink tubing **$15.00**

PARTS FOR THE 6GHz+ TOUCHSCREEN FREQUENCY COUNTER *(OCT 17)*
- Explore 100 kit (Cat SC3834; no LCD included) **$69.90**
- One ERA-2SM+ & one ADCH-80A+ (Cat SC1167; **two required**) **$15.00/pk.**

MICROBRIDGE COMPLETE KIT (CAT SC4264) *(MAY 17)*
- PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF) **$20.00**

STATIONMASTER (CAT SC4187) *(MAR 17)*
- Hard to get parts: DRV8871 IC, SMD 1µF capacitor and 100kΩ potentiometer with detent **$12.50**

VARIOUS MODULES & PARTS
- ISD1820-based voice recorder / playback module (Junk Mail Repeller, AUG19) **$4.00**
- 23LCV1024-I/P SRAM (DIP) and MCP73831T charger ICs (UHF Repeater, MAY19) **$11.50**
- MCP1700 3.3V LDO regulator (suitable for USB Mouse & Keyboard Adapator, FEB19) **$1.50**
- LM4865MX amplifier IC & LF50CV regulator (Tinnitus/Insomnia Killer, NOV18) **$10.00**
- 2.8-inch touchscreen LCD module with SD card socket (Tide Clock, JUL18) **$22.50**
- ESP-01 WiFi Module (El Cheapo Modules, Part 15, APR18) **$5.00**
- MC1496P double-balanced mixer IC (DIP-14) (AM Radio Transmitter, MAR18) **$2.50**
- WiFi Antennas with U.FL/IPX connectors (Water Tank Level Meter with WiFi, FEB18): 5dBi – **$12.50** ~ 2dBi (omnidirectional) – **$10.00**
- NRF24L01+PA+NA transceiver with SNA connector and antenna (El Cheapo 12, JAN18) **$5.00**
- WeMos D1 Arduino-compatible boards with WiFi (SEPT17, FEB18): ThingSpeak data logger – **$10.00** ~ WiFi Tank Level Meter (ext. antenna socket) – **$15.00**
- Geeetech Arduino MP3 shield (Arduino Music Player/Recorder, VS1053, JUL17) **$20.00**
- 1nF 1% MKP (5mm lead spacing) or ceramic capacitor (Wide-Range LC Meter, JUN18) **$2.50**
- MAX7219 LED controller boards (El Cheapo Modules, Part 7, JUN17): 8x8 red SMD/DIP matrix display – **$5.00** ~ red 8-digit 7-segment display – **$7.50**
- AD9833 DDS module (with gain control) (for Micromite DDS, APR17) **$25.00**
- AD9833 DDS module (no gain control) (El Cheapo Modules, Part 6, APR17) **$15.00**
- CP2102 USB-UART bridge **$5.00**
- microSD card adaptor (El Cheapo Modules, Part 3, JAN17) **$2.50**
- DS3231 real-time clock module with mounting spacers and screws (El Cheapo, OCT16) **$5.00**

THESE ARE ONLY THE MOST RECENT MICROS AND SPECIALISED COMPONENTS. FOR THE FULL LIST, SEE www.siliconchip.com.au/shop

*Prices valid for month of magazine issue only. All prices in Australian dollars and include GST where applicable. **# P&P prices are within Australia. O'seas? Place an order on our website for an accurate quote.**

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB ONLY. If you want a kit, check our store or contact the kit suppliers advertising in this issue. For unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP Online Shop has boards going back to 2001 and beyond. For a complete list of available PCBs etc, go to *siliconchip.com.au/shop/8* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017	SC4281	$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
3-WAY ADJUSTABLE ACTIVE CROSSOVER CASE PIECES	SEPT 2017	SC4403	$10.00
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00
6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017	SC4444	$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	06111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017	SC4464	$25.00
THEREMIN	JAN 2018	23112171	$12.50
PROPORTIONAL FAN SPEED CONTROLLER	JAN 2018	05111171	$2.50
WATER TANK LEVEL METER (INCLUDING HEADERS)	FEB 2018	21110171	$7.50
10-LED BARAGRAPH	FEB 2018	04101181	$7.50
10-LED BARAGRAPH SIGNAL PROCESSING	FEB 2018	04101182	$5.00
TRIAC-BASED MAINS MOTOR SPEED CONTROLLER	MAR 2018	10102181	$10.00
VINTAGE TV A/V MODULATOR	MAR 2018	02104181	$7.50
AM RADIO TRANSMITTER	MAR 2018	06101181	$7.50
HEATER CONTROLLER	APR 2018	10104181	$10.00
DELUXE FREQUENCY SWITCH	MAY 2018	05104181	$7.50
USB PORT PROTECTOR	MAY 2018	07105181	$2.50
2 x 12V BATTERY BALANCER	MAY 2018	14106181	$2.50
USB FLEXITIMER	JUNE 2018	19106181	$7.50
WIDE-RANGE LC METER	JUNE 2018	04106181	$5.00
WIDE-RANGE LC METER (INCLUDING HEADERS)	JUNE 2018	SC4618	$7.50
WIDE-RANGE LC METER CLEAR CASE PIECES	JUNE 2018	SC4609	$7.50
TEMPERATURE SWITCH MK2	JUNE 2018	05105181	$7.50
LiFePO4 UPS CONTROL SHIELD	JUNE 2018	11106181	$5.00
RASPBERRY PI TOUCHSCREEN ADAPTOR (TIDE CLOCK)	JULY 2018	24108181	$5.00
RECURRING EVENT REMINDER	JULY 2018	19107181	$5.00
BRAINWAVE MONITOR (EEG)	AUG 2018	25107181	$10.00
SUPER DIGITAL SOUND EFFECTS	AUG 2018	01107181	$2.50
DOOR ALARM	AUG 2018	03107181	$5.00
STEAM WHISTLE / DIESEL HORN	SEPT 2018	09106181	$5.00
DCC PROGRAMMER	OCT 2018	09107181	$5.00
DCC PROGRAMMER (INCLUDING HEADERS)	OCT 2018	09107181	$7.50
OPTO-ISOLATED RELAY (WITH EXTENSION BOARDS)	OCT 2018	10107181/2	$7.50
GPS-SYNCHED FREQUENCY REFERENCE	NOV 2018	04107181	$7.50
LED CHRISTMAS TREE	NOV 2018	16107181	$5.00
DIGITAL INTERFACE MODULE	NOV 2018	16107182	$2.50
TINNITUS/INSOMNIA KILLER (JAYCAR VERSION)	NOV 2018	01110181	$5.00
TINNITUS/INSOMNIA KILLER (ALTRONICS VERSION)	NOV 2018	01110182	$5.00
HIGH-SENSITIVITY MAGNETOMETER	DEC 2018	04101011	$12.50
USELESS BOX	DEC 2018	08111181	$7.50
FOUR-CHANNEL DC FAN & PUMP CONTROLLER	DEC 2018	05108181	$5.00
ATtiny816 DEVELOPMENT/BREAKOUT BOARD	JAN 2019	24110181	$5.00
ISOLATED SERIAL LINK	JAN 2019	24107181	$5.00
DAB+/FM/AM RADIO	JAN 2019	06112181	$15.00
TOUCH & IR REMOTE CONTROL DIMMER MAIN PCB	FEB 2019	10111191	$10.00
REMOTE CONTROL DIMMER MOUNTING PLATE	FEB 2019	10111192	$10.00
REMOTE CONTROL DIMMER EXTENSION PCB	FEB 2019	10111193	$10.00
MOTION SENSING SWITCH (SMD) PCB	FEB 2019	05102191	$2.50
USB MOUSE AND KEYBOARD ADAPTOR PCB	FEB 2019	24311181	$5.00
REMOTE-CONTROLLED PREAMP WITH TONE CONTROL	MAR 2019	01111119	$25.00
PREAMP INPUT SELECTOR BOARD	MAR 2019	01111112	$15.00
PREAMP PUSHBUTTON BOARD	MAR 2019	01111113	$5.00
DIODE CURVE PLOTTER	MAR 2019	04112181	$7.50
FLIP-DOT COIL	APR 2019	19111181	$5.00
FLIP-DOT PIXEL (INCLUDES 16 PIXELS)	APR 2019	19111182	$5.00
FLIP-DOT FRAME (INCLUDES 8 FRAMES)	APR 2019	19111183	$5.00
FLIP-DOT DRIVER	APR 2019	19111184	$5.00
FLIP-DOT (SET OF ALL FOUR PCBS)	APR 2019	SC4950	$17.50
iCESTICK VGA ADAPTOR	APR 2019	02103191	$2.50
UHF DATA REPEATER	MAY 2019	15004191	$10.00
AMPLIFIER BRIDGE ADAPTOR	MAY 2019	01105191	$5.00
3.5-INCH SERIAL LCD ADAPTOR FOR ARDUINO	MAY 2019	24111181	$5.00
DSP CROSSOVER/EQUALISER ADC BOARD	MAY 2019	01106191	$7.50
DSP CROSSOVER/EQUALISER DAC BOARD	MAY 2019	01106192	$7.50
DSP CROSSOVER/EQUALISER CPU BOARD	MAY 2019	01106193	$5.00
DSP CROSSOVER/EQUALISER PSU BOARD	MAY 2019	01106194	$7.50
DSP CROSSOVER/EQUALISER CONTROL BOARD	MAY 2019	01106195	$5.00
DSP CROSSOVER/EQUALISER LCD ADAPTOR	MAY 2019	01106196	$2.50
DSP CROSSOVER (SET OF ALL BOARDS – TWO DAC)	MAY 2019	SC5023	$40.00
STEERING WHEEL CONTROL IR ADAPTOR	JUNE 2019	05105191	$5.00
GPS SPEEDO/CLOCK/VOLUME CONTROL	JUNE 2019	01104191	$7.50
RF SIGNAL GENERATOR	JUNE 2019	04106191	$15.00
RASPBERRY PI SPEECH SYNTHESIS/AUDIO	JULY 2019	01106191	$5.00
BATTERY ISOLATOR CONTROL BOARD	JULY 2019	05106191	$7.50
BATTERY ISOLATOR MOSFET BOARD (2oz)	JULY 2019	05106192	$10.00
MICROMITE LCD BACKPACK V3	AUG 2019	07106191	$7.50
CAR RADIO DIMMER ADAPTOR/VOLTAGE INTERCEPTOR	AUG 2019	05107191	$5.00
PSEUDO-RANDOM NUMBER GENERATOR (LFSR)	AUG 2019	16106191	$5.00
4DoF SIMULATION SEAT CONTROLLER BOARD	SEPT 2019	11109191	$7.50
HIGH-CURRENT H-BRIDGE MOTOR DRIVER	SEPT 2019	11109192	$2.50
MICROMITE EXPLORE-28 (4-LAYERS)	SEPT 2019	07108191	$5.00
SIX INPUT AUDIO SELECTOR MAIN BOARD	SEPT 2019	01110191	$7.50
SIX INPUT AUDIO SELECTOR PUSHBUTTON BOARD	SEPT 2019	01110192	$5.00
ULTRABRITE LED DRIVER	SEPT 2019	16109191	$2.50

NEW PCBs

HIGH RESOLUTION AUDIO MILLIVOLTMETER	**OCT 2019**	**04108191**	**$10.00**
PRECISION AUDIO SIGNAL AMPLIFIER	**OCT 2019**	**04107191**	**$5.00**

WE ALSO SELL AN A2 REACTANCE WALLCHART, RTV&H DVD, VINTAGE RADIO DVD PLUS VARIOUS BOOKs IN THE "Books, DVDs, etc" PAGE AT SILICONCHIP.COM.AU/SHOP/3

Low cost . . . Easy to build . . . Highly accurate . . . An essential piece of test equipment!

ARDUINO-BASED DIGITAL AUDIO MILLIVOLTMETER

If your hobby or business involves audio – at any level – you really must have an audio millivoltmeter in your test gear arsenal. Once you've used one, you'll wonder how you managed without it. It's useful for setting up and calibrating audio systems, doing performance measurements and troubleshooting audio equipment, and much more. This one doesn't just measure low-level signals. It provides high-resolution measurements of balanced or unbalanced audio signals from below -85dBV (56µV RMS) to above +35dBV (60V RMS)! It's easy to build and has automatic range switching and can log data to a PC.

by Jim Rowe

Features & specifications

- Description: *A compact high-resolution digital audio millivolt/voltmeter with balanced and unbalanced inputs, backlit LCD readout, automatic range switching and the ability to send its data to a PC.*
- Unbalanced measurement range: *from <56µV RMS (-85dBV) to 60V RMS (+35dBV)*
- Balanced measurement range: *from <56µV RMS (-85dBV) to 600mV RMS (-4.5dBV)*
- Frequency range: *5Hz-110kHz (+0/-3dB); 20Hz-70kHz (+0/-0.5dB); 50Hz-45kHz (+0/-0.1dB)*
- Resolution: *24 bits (1 part in 16,777,215)*
- Measurement linearity: *±0.3dB*
- Basic accuracy: *approximately ±0.1% after calibration*
- Input Impedance: *1MΩ/10kΩ (unbalanced input) or 760kΩ (balanced input)*
- Maximum input level: *as per measurement ranges*
- Power supply: *5V DC via USB mini Type-B socket, either from a USB charger or a PC USB port*
- Current drain: *<78mA (390mW at 5V)*

We decided to design a new audio millivoltmeter because we wanted one which worked over a very wide range of signal amplitudes with excellent accuracy and resolution.

We also wanted to provide the ability to measure balanced or unbalanced audio signals without the need for any additional hardware. But most of all, we wanted it to be easy to build and would fit in a compact case.

So why build this one instead of our previous audio millivoltmeter (March 2009 – siliconchip.com.au/Article/1372)?

For many reasons, this new unit makes that old one obsolete:

- It can measure smaller signals and much larger signals.
- It has much better resolution.
- Its frequency response (on both ranges) is much better (see Fig.1).
- It has a built-in balanced input (no separate converter required).
- It does not require manual range selection
- It runs off USB power.
- It is quite a bit smaller.

Some of the improvements in this version are due to our use of an Arduino Nano MCU module for control, while most of the performance improvements are due to our use of an LTC2400 24-bit analog-to-digital converter (ADC).

This gives much higher measurement resolution than the 10-bit ADC built into most Arduinos.

The result is a unit that's much more convenient to use, with higher performance and it fits into a diecast box measuring only 119 x 94 x 57mm. That's less than half the volume of the earlier version.

We estimate the total cost for everything you'll need to build this project to be under $250, including GST. That compares more than favourably with what you'd pay for a similar commercial instrument.

To give you an idea of why you might want to measure down to -85dBV, if you have a 100W amplifier which can drive 8Ω loads, at full power it's delivering 28.28V RMS ($\sqrt{(100W \times 8\Omega)}$) across the speaker. That equates to +29dBV.

For such an amplifier, a noise level of -85dBV therefore would mean a signal-to-noise ratio of 114dB (85dB + 29dB). A good amplifier can achieve that.

So if you had a meter which couldn't measure down to -85dB, you couldn't come close to getting an accurate measurement of the signal-to-noise ratio of such an amplifier.

The best our 2009 design could achieve was -76dBV, limiting you to SNR measurements of no better than

Some potential uses:

- Audio performance measurements (signal-to-noise ratio, frequency response, sensitivity, power output, channel separation, crosstalk, amplifier gain etc)
- Crossover adjustment
- Equalisation and room response adjustments (in combination with a microphone & preamp)
- Amplifier calibration
- Amplifier & preamplifier trouble-shooting and repair

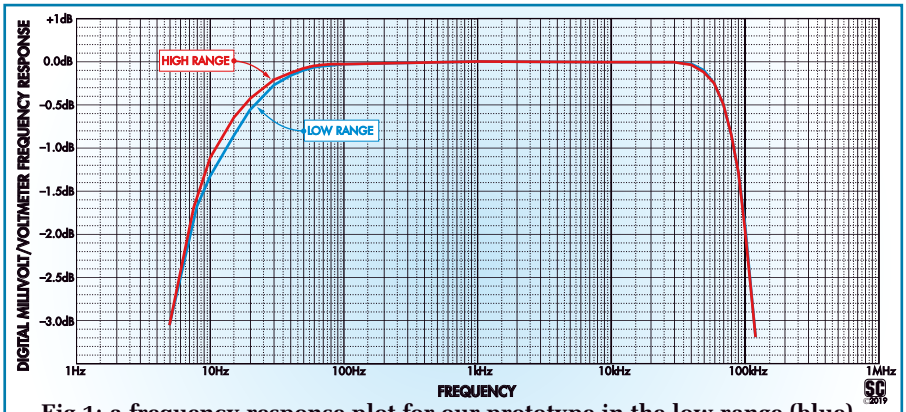


Fig.1: a frequency response plot for our prototype in the low range (blue) (measured at 600mV RMS) and high range (red). This demonstrates that the reading is within 0.5dB of the actual signal amplitude over the entire audible range and beyond. It's within 0.1dB from 50Hz to 45kHz.

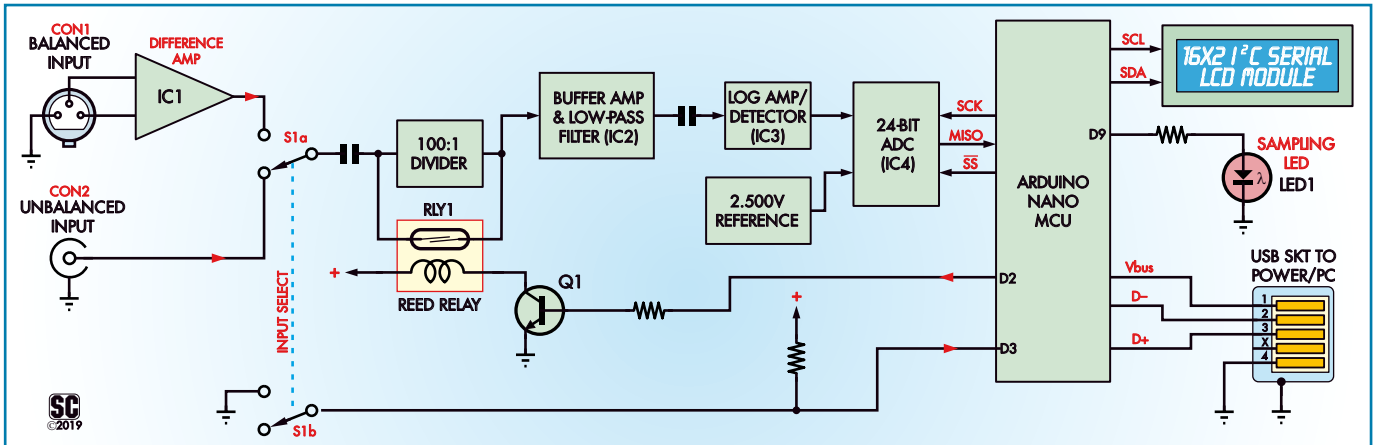


Fig.2: this block diagram shows the operating principle of the Meter. IC1 converts a balanced signal to unbalanced and S1 selects between the two inputs. The signal then either passes through RLY1 or a 100:1 divider, depending on whether Q1 (and therefore RLY1) is energised, giving the unit its two ranges. The signal is then buffered, filtered and fed to the logarithmic detector before passing to the ADC and onto the Arduino.

about 105dB for a 100W amp, and considerably worse than that for lower-powered amplifiers, or line-level devices.

How it works

Fig.2 is a simplified block diagram of the new meter. At its heart is IC3, an Analog Devices AD8307 logarithmic amplifier/detector. This is the same device used in our earlier meter.

The AD8307 has impressive specifications: it can convert AC signals into a DC voltage equivalent, following a logarithmic 'law' of 25mV per dB (typically linear to within ±0.3dB) and with a span of just on 100dB. The device also operates up to around 500MHz, so it's just 'idling' at audio frequencies.

In the new meter, we are feeding IC3's output to IC4, an LTC2400 24-bit delta/sigma ADC. This measures the output of IC3 relative to an accurate 2.500V DC provided by an LT1019

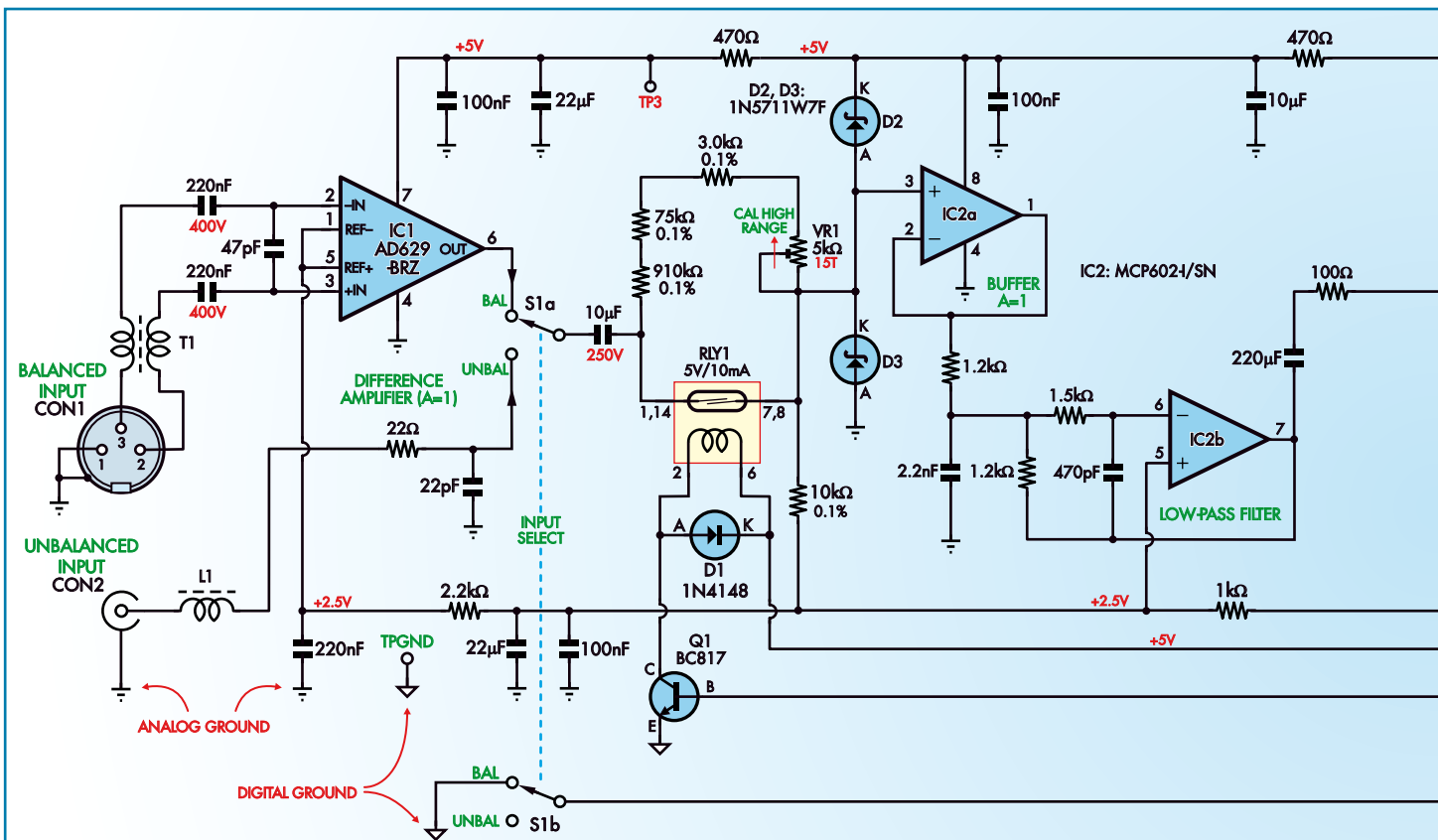


Fig.3: the full circuit follows much the same pattern as Fig.2, but you can see that some details were left out of the earlier diagram, such as the input RF filtering. VR1 allows the 100:1 divider to be accurately trimmed while VR2 calibrates the output of the log detector.

SC ©2019 **DIGITAL AUDIO MILLIVOLT/VOLTMETER**

bandgap voltage reference. The resulting 24-bit digital samples are passed to the Arduino Nano via SPI (serial peripheral interface).

The microcontroller then processes the samples to calculate the corresponding measurements, which are displayed on the LCD module shown at upper right in Fig.2.

They're also sent out via the D- and D+ lines of the USB socket at lower right, for logging via a PC if required. The micro gives an indication of when sampling is taking place by lighting LED1.

The elements on the left-hand side of Fig.2 have been added to provide input buffering, low-pass filtering (to reject RF or other unwanted signals), range selection and selection between the unbalanced and balanced inputs.

IC1 is an AD629B high common-mode voltage rejecting difference amplifier, used to convert the balanced input signals from XLR socket CON1 into an unbalanced signal. Switch S1a then selects between the unbalanced signals from either CON2 or the output of IC1, with the other half of the double-pole switch (S1b) allowing the micro to detect which input is currently selected.

The signal then goes into the range switching section, where a reed relay controlled by the micro via transistor Q1 is used to select between either the input signal divided by 100 (for the high range, up to 60V), or bypassing the divider (for the low range).

The signal is then fed to IC2, a dual op amp with the first stage used as a unity-gain buffer and the second stage as a low-pass filter.

This removes, or at least significantly reduces, any noise (including digital switching artefacts from the control circuitry) which may be induced into the analog signal.

The full circuit

You'll find more details in the main circuit diagram (Fig.3). The signal from the balanced input at CON1 is filtered using a common-mode choke (T1) and a 47pF capacitor to remove RF signals, before being coupled via two high-voltage capacitors to the inputs of IC1, the balanced-to-unbalanced converter.

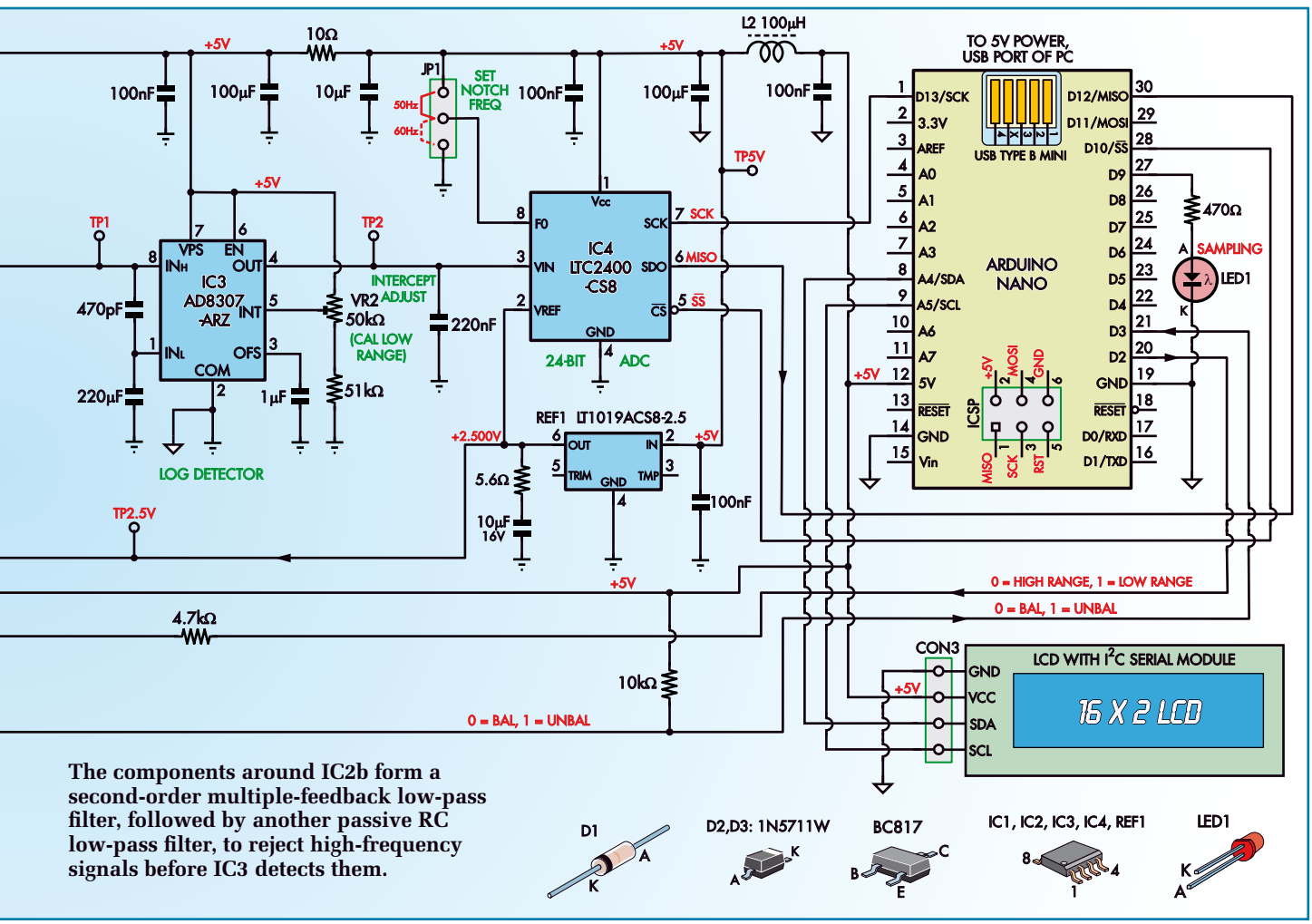
This allows for balanced common-mode signals up to 400V peak from Earth.

A 2.5V bias signal is applied to the REF- and REF+ inputs of IC1 (pins 1 & 5), biasing its input signals to half of the 5V supply, to allow for a symmetrical signal swing before it runs into clipping.

The signal from the unbalanced input, CON2, is also RF filtered using inductor L1 and a 22Ω series resistor and 22pF capacitor to ground.

The output from selector switch S1 is AC-coupled to the precision 100:1 voltage divider, the upper portion of which is shorted out when the contacts of RLY1 are closed for measuring lower level signals. Trimpot VR1 is used to 'fine-tune' the divider for calibrating the Meter's HIGH range.

The way the divider works, and the reason for selecting these exact component values, is shown in more detail in Fig.4.



The components around IC2b form a second-order multiple-feedback low-pass filter, followed by another passive RC low-pass filter, to reject high-frequency signals before IC3 detects them.

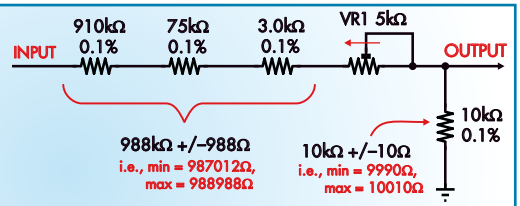

910kΩ
0.1%
75kΩ
0.1%
3.0kΩ
0.1%
VR1 5kΩ
INPUT
OUTPUT
10kΩ
0.1%
988kΩ +/–988Ω
i.e., min = 987012Ω,
max = 988988Ω
10kΩ +/–10Ω
i.e., min = 9990Ω,
max = 10010Ω
To achieve exact 100:1 divider ratio, we must be able to set total upper arm resistance to 99 times lower arm resistance. This means VR1 must be able to set the upper arm resistance to within this range: 989010 – 990990Ω
So VR1 must have range of from 22Ω to 3.978kΩ

Fig.4: the details of the precision 100:1 divider. Starting with the choice of a 10kΩ 0.1% resistor in the bottom leg (which can have a value from 9.99kΩ to 10.01kΩ), that means we need a total resistance in the upper leg of 990kΩ±990Ω. Taking into account the tolerance of the fixed resistors in that upper leg, a 5kΩ potentiometer gives sufficient scope for adjusting for precisely the right attenuation factor.

The values are selected so that trimpot VR1 can be used to set the divider ratio to precisely 100:1 without restricting its rotation to a narrow portion of its range. VR1 can compensate for within-tolerance variations in the four 0.1% tolerance fixed resistors.

Note that as well as forming the lower leg of the divider for the Meter's HIGH range, the 10kΩ 0.1% resistor also forms the input resistance for the Meter's LOW range, for the unbalanced input.

That's because when RLY1 is switched on to short out the divider's upper arm for the LOW range, the lower part of the divider still provides the DC bias for input pin 3 of IC2a.

Pin 21 of the Arduino (the D3 digital input) is used to monitor the position of S1, while pin 20 (digital output D2) controls the range selection relay (RLY1) via NPN transistor Q1. Diode D1 protects transistor Q1 from damage due to the back-EMF generated by the coil of RLY1 when it switches off.

Schottky diodes D2 and D3 protect IC2a from overload damage, by clamping its pin 3 input voltage within a few hundred millivolts of the supply rails, even if the input signal amplitude is too high for the meter to measure accurately.

The purpose of IC2a is to buffer the signal from the divider to provide a low-impedance source for the following low-pass filter, which is built around the other half of the dual op amp, IC2b.

This is a second-order (-12dB/octave) 'multiple feedback' low-pass filter with a -3dB point of around 52kHz. This was chosen to give a very flat response up to 20kHz, then a steep roll-off above audio frequencies.

This filter is important since, as stated earlier, the log converter (IC3) has a wide bandwidth of up to 500MHz. So any digital noise or RF picked up before this point will add to the signal being detected and give erroneous readings. Therefore, we want to ensure that all ultrasonic frequency signals are severely attenuated.

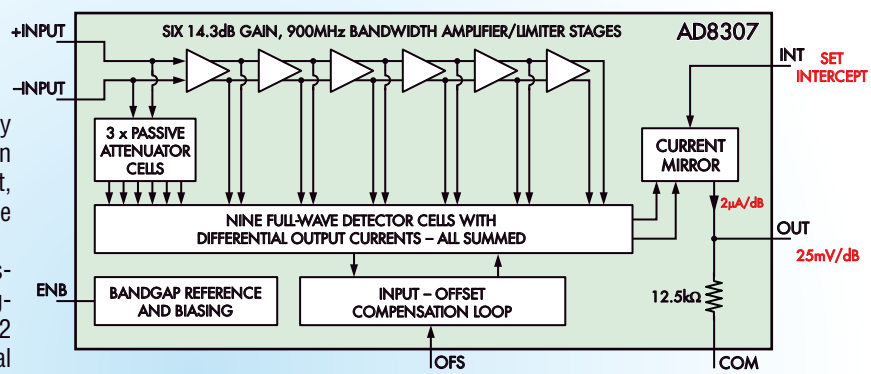
This filter type and its values were chosen carefully for this role, as a multiple-feedback filter has a significant advantage over the more common Sallen-Key type in that it still provides excellent attenuation for signals above the op amp's bandwidth, and it is far less reliant on said bandwidth to provide the expected filter attenuation.

This was all explained in detail on pages 44 & 45 of the May 2018 issue, in an article titled "LTspice Simulation: Analysing/Optimising Audio Circuits" (**siliconchip.com.au/Article/11063**). A second-order multiple-feedback resistor needs just one more resistor than a Sallen-Key type, which is well worth it for its superior high-frequency attenuation.

The inputs of IC2a & IC2b are biased to the 2.5V rail, both through its connection to the bottom of the switchable voltage divider ladder, as well as it being fed directly to pin 5 of IC2b.

Again, this biases the AC signal fed to these rail-to-rail op amps so that it swings symmetrically within the 5V supply.

The AD8307 logarithmic amplifier/detector



Logarithmic amplifier/detector ICs are a fairly specialised but quite useful device. You can get an idea of how they work from the diagram at right, which gives a simplified view of what's inside the AD8307 device.

The incoming AC signals pass through six cascaded wideband differential amplifier/limiter stages, each of which has a gain of 14.3dB (about 5.2 times) before it enters limiting. This gives a total gain of about 86dB, or around 20,000 times.

The outputs of each amplifier/limiter stage are fed to a series of nine full-wave detector cells, along with similar outputs from three cascaded passive 14.3dB attenuator cells connected to the input of the first amplifier/limiter.

The differential current-mode outputs of all nine detector cells are added together and fed to a 'current mirror' output stage, which effectively converts them into a direct current.

Because of the combination of cascaded gain and limiting in the amplifiers (plus an internal offset compensation loop), the amplitude of this output current is proportional to the logarithm of the AC input voltage.

This holds true over an input range of just on 100dB, from about -93dBV (22.4µV) up to +7.0dBV (2.24V). This logarithmic relationship is linear to within ±0.3dB over most of the range.

The output current (I_{OUT}) increases at a slope of very close to 2µA per dB increase in AC input level, and when this current passes through a 12.5kΩ load resistor inside the chip, the result is a DC output voltage of 25mV/dB. This slope can be fine-tuned using an external adjustable resistor in parallel with the 12.5kΩ internal resistor.

The "set intercept" (SI) pin allows you to adjust the DC offset in the output current mirror, which sets the effective zero level point of the chip's output current and voltage, ie, the origin from which the output slope rises.

The audio signal is then AC-coupled to input pin 8 of the AD8307 log detector. A 100Ω series resistor provides additional RF filtering, in combination with the 470pF capacitor between its pins 8 and 1. Pin 1 is grounded via a 220µF capacitor, as we are not feeding differential signals to this chip. The INL input sits at the chip's DC bias level while the INH input swings above and below that voltage.

Trimpot VR2 allows us to adjust IC3's 'intercept' point, calibrating the Meter's LOW measurement range. A 1µF capacitor smoothes the logarithmic output voltage from pin 4, and this is then fed to the analog input of IC4, the 24-bit ADC.

JP1, connected to pin 8 of IC4, changes the ADC's internal sampling frequency to provide a 'notch' for rejecting either 50Hz or 60Hz 'hum' in the signal from IC3.

So for use in Australia, it would be set in the upper (50Hz) position, while for use in the USA and other countries with 60Hz mains power, you'd set it in the lower position.

REF1 provides a very stable 2.5V reference to IC4, necessary for it to operate with the high precision possible for a 24-bit ADC. This means its resolution is 149nV (2.5V ÷ 2^{24}), so the limiting factor in its performance will be system noise.

The reference has an initial tolerance of ±0.05%, which equates to ±1.25mV. REF1's output also provides the 2.5V biasing for IC1 & IC2 mentioned earlier.

The reference output is stabilised by a Zobel network (5.6Ω & 10µF), as recommended in its data sheet.

The Arduino Nano communicates with the ADC (IC4) with the standard SPI pins (ie, pins D10, D12 & D13) while communication with the LCD is via an I^2C bus at pins A4/SDA and A5/SCL. Sampling LED1 is driven from the D9 digital output.

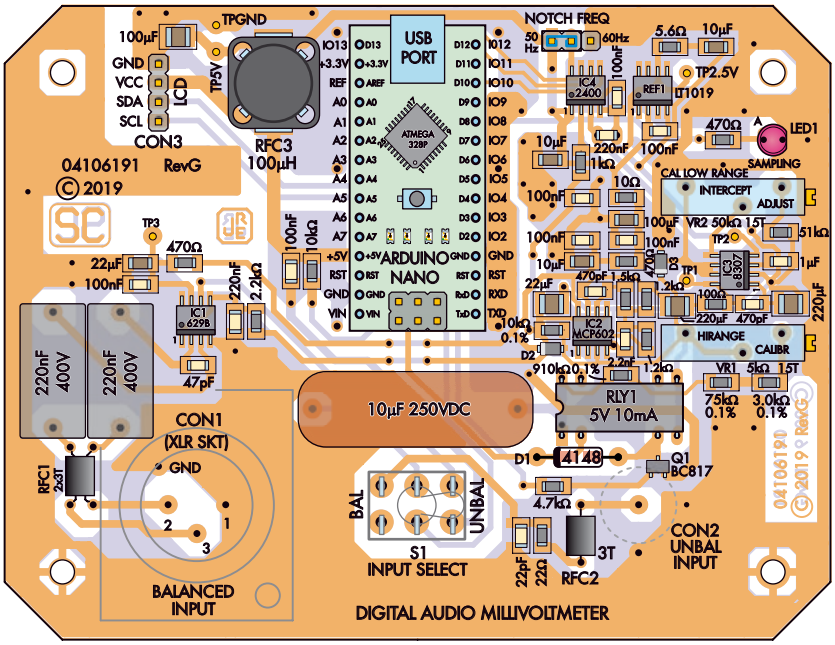
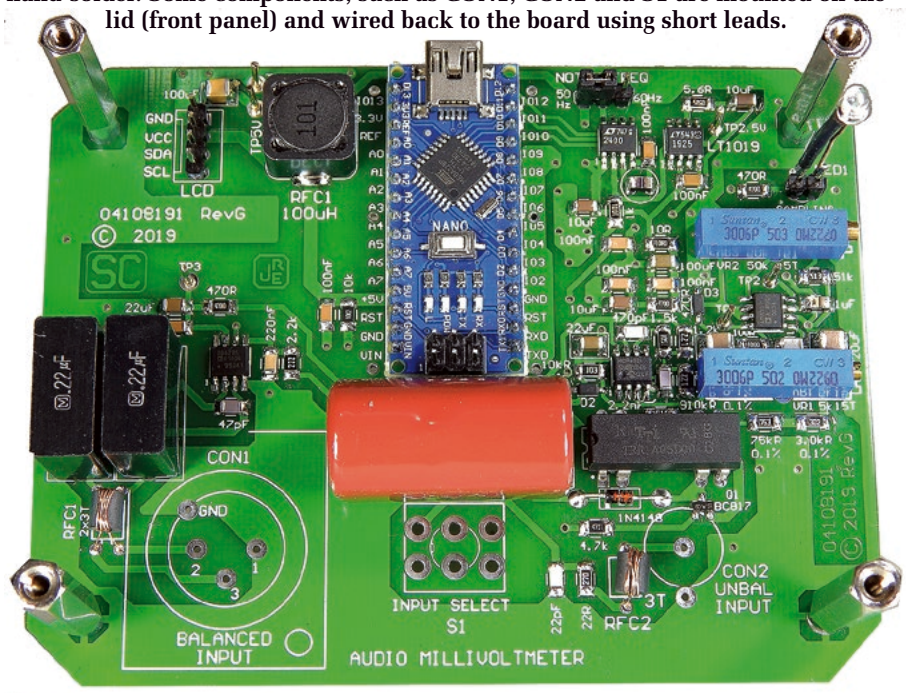


Fig.5: this PCB overlay diagram (and photo below) shows where the components are mounted on the PCB, including the prebuilt Arduino Nano microcontroller module. Most of the components are larger SMD types which are not difficult to hand-solder. Some components, such as CON1, CON2 and S1 are mounted on the lid (front panel) and wired back to the board using short leads.



Construction

Most of the circuitry and components of the new Meter (including the Arduino Nano) are mounted on a PCB measuring 109 x 84mm and coded 04106191.

The only components not mounted on the PCB are the LCD module, the input connectors and input selector switch S1. These mount on the box front panel and connect to the PCB via short lengths of wire.

Some of the components on the PCB are of the through-hole variety and somewhat larger than the SMD components. So it's best to fit the smaller SMD parts first.

The location and orientation of all parts are shown on the PCB overlay diagram (Fig.5), but you can also refer to the photos. Note though that there may be some slight differences between the prototype and final PCBs.

There are no fine-pitch SMD parts; all of them are reasonably generous in terms of size and pin spacings, so they are not difficult to handle. Start by fitting all the SMD passives (resistors and capacitors), except for those which are right next to one of the SMD ICs, as these would otherwise make fitting the latter more tricky.

The usual technique is to tack one side of the component onto its pad, make sure it is sitting flat on the board and properly aligned, then solder the opposite pad (after waiting long enough for the first joint to solidify). Then wait a little longer and refresh

Parts list – Digital Audio Millivoltmeter

1 119 x 94 x 57mm diecast aluminium box [Jaycar Cat HB-5064 or similar]
1 double-sided PCB, 109 x 84mm, code 04108191 (RevH)
1 Arduino or Duinotech Nano MCU module
1 USB Type-A to mini Type-B cable
1 16x2 backlit alphanumeric LCD module with I^2C serial interface
[eg, Silicon Chip Online Shop Cat SC4198]
1 panel-mount miniature DPDT toggle switch (S1) [Jaycar ST035, Altronics S1345]
1 panel-mount 3-pin female XLR connector (CON1) [Jaycar PS1930, Altronics P0804]
1 panel-mount BNC socket (CON2)
1 4-pin header, 2.54mm pitch (CON3)
1 4-pin female header socket, 2.54mm pitch (to connect LCD module)
1 2-pin header, 2.54mm pitch (for LED1)
1 3-pin header with jumper shunt (JP1)
1 SPST DIL reed relay with 5V/10mA coil (RLY1) [Jaycar Cat SY-4030 or similar]
2 5mm-long ferrite beads, 4mm outer diameter (L1,T1)
[Jaycar Cat LF-1250 or similar]
1 300mm length of 0.25mm diameter enamelled copper wire (for L1 & T1)
1 100µH SMD RF inductor (L2) [Jaycar Cat LF-1402 or similar]
4 25mm-long M3 tapped spacers
4 6mm-long untapped spacers
8 12mm or 15mm-long M3 panhead machine screws
2 9mm-long M3 countersunk head machine screws
2 M3 hex nuts and star lockwashers
4 16mm or 20mm-long M2.5 countersunk head machine screws
4 9mm-long untapped spacers, >2.5mm inner diameter
4 M2.5 hex nuts
6 PCB pins (optional; for TPGND, TP2.5V, TP5V & TP1-TP3)

Semiconductors
1 AD629BRZ high common mode voltage difference amplifier, SOIC-8 (IC1)
1 MCP602-I/SN dual rail-to-rail input/output op amp, SOIC-8 (IC2)
1 AD8307ARZ logarithmic amplifier/detector, SOIC-8 (IC3)
1 LTC2400CS8#PBF 24-bit ADC, SOIC-8 (IC4)
1 LT1019ACS8-2.5#PBF precision 2.500V voltage reference, SOIC-8 (REF1)
1 BC817-40 NPN transistor, SOT-23 (Q1)
1 3mm red LED (LED1)
1 1N4148 silicon small signal diode (D1)
2 1N5711W-7-F schottky diodes, SOD-123 (D2,D3)

Capacitors (all SMD ceramic, 3216/1206 size unless otherwise stated)
2 220µF 6.3V X5R, SMD 3226/1210 size
2 100µF 6.3V X5R
2 22µF 10V X5R
3 10µF 16V X7R
1 10µF 250VDC metallised polypropylene,radial leaded [Panasonic ECQ-E2106KF]
1 1µF 50V through-hole ceramic or MKT
1 1µF 16V X7R
2 220nF 275VAC metallised polypropylene, radial leaded [Panasonic ECQ-U2A224ML]
1 220nF 16V X7R *(Code 220, 0.22 or 220n)*
7 100nF 16V X7R *(Code 100, 0.1 or 100n)*
1 2.2nF 16V X7R *(Code 2.2, .022 or 2n2)*
2 470pF 100V C0G/NP0 *(Code 470, .0047 or 470p)*
1 47pF 100V C0G/NP0 *(Code 47, .00047 or 47p)*
1 22pF 250V C0G/NP0 *(Code 22, .00022 or 22p)*

Resistors (all SMD 1% 0.25W, 3216/1206 size unless otherwise stated)

1 910kΩ 0.1%	1 75kΩ 0.1%	1 51kΩ	1 10kΩ	1 10kΩ 0.1%	
1 3.0kΩ 0.1%	1 4.7kΩ	1 2.2kΩ	1 1.5kΩ	2 1.2kΩ	
1 1kΩ	1 100Ω	3 470Ω	1 22Ω	1 10Ω	1 5.6Ω

1 5kΩ multi-turn horizontal trimpot (VR1)
1 50kΩ multi-turn horizontal trimpot (VR2)

the first joint with a little extra solder or flux paste.

With those passives all in place, you can install the five SMD ICs. In each case, they must be orientated correctly, so find the pin 1 dot or divot on the top face, and make sure it's facing as shown in Fig.5. If you can't find the dot, pin 1 is normally also indicated by a chamfered edge on just that side of the IC.

Again, locate the IC and tack one pin down before soldering the other seven pins, then refresh that initial joint. The pins are spaced far enough apart to be soldered individually. If you accidentally form a solder bridge between two pins, add a little flux paste and then clean it up using solder wick.

You can now fit the remaining SMD passives, plus the two SMD diodes, ensuring their cathode stripes face as shown in Fig.5.

Next, fit transistor Q1. It has three pins, so its orientation should be obvious. Make sure its leads are sitting flat on the PCB before you solder it in place.

The last SMD component is L2, which is quite large. Spread a thin smear of flux paste on both pads before you start.

You will need a hot iron to form good solder joints due to the thermal masses of both the PCB and the part. Make sure you add enough solder and heat it long enough to form good fillets.

Through-hole parts

Before proceeding, we need to wind choke L1 and transformer/common-mode choke T1. These are both wound on 5mm-long ferrite beads, using 0.25mm diameter enamel coated copper wire.

L1 has three single turns, while T1 has three bifilar turns, wound by first folding a 200mm length of the wire in two, and then using the 'doubled pair' to wind their three turns together.

Once both chokes are wound, cut off the wire ends about 8mm from the ends of the ferrite beads, scrape off about 4mm of the enamel and then lightly tin the wire ends so they will be easy to solder into the PCB pad holes.

Just before you solder in the four wires for T1, use your DMM to make sure that the wire pairs do not 'cross over'; the left-most upper and lower wires should be joined together, as should the right-most upper and lower wires.

You can now proceed to fit the remaining through-hole parts. Start with diode D1 (as usual, be careful with its orientation). It's then a good idea to install the six PC pins, if you are going to use them. These make it easier to use clip leads to connect your DMM to the board during testing and calibration. These are for TPGND, TP2.5V, TP5V and TP1-TP3.

Next, mount the reed relay, again taking care with its polarity. Follow with the two multi-turn trimpots, which are different values (so don't get them mixed up), followed by the 4-pin header for CON3, the 3-pin header for JP1 and the 2-pin header used to facilitate the connection of LED1.

Now is also a good time to install the 1µF through-hole capacitor, near IC4.

Before you mount the Nano board, you will need to fit a short length of wire shorting out its onboard diode D1, on the underside; see the sidebar photo and text for an explanation of why this is necessary and how to do it.

Now solder the Arduino Nano module to the rows of pads on the board, with its USB connector over the outside edge. Make sure it's pushed all the way down before soldering; it's a good idea to solder two diagonal pins first, check that it's flat and then solder the rest.

Finish up by mounting the three large capacitors.

The final step at this stage is to solder the leads of LED1 to the pins of the 2-pin header fitted to the PCB, taking care to connect them to the correct pin (the longer anode pin goes to the inner pin marked "A"). The leads should be soldered to the pins so that the underside of the LED's body is 28mm above the top of the PCB.

Your Meter's PCB assembly should now be complete and ready to be fitted into the box, once it has been prepared.

Before you do so, though, plug the 4-pin female socket onto CON3 and place the shorting block in the correct position on JP1, to suit your local mains frequency.

Preparing the box

Most of the holes you'll need to drill or cut in the box are in the lid, which becomes the Meter's front panel.

There are only three holes to be cut in the base of the box: two circular holes in the right-hand end for access to trimpots VR1 and VR2, and one rectangular hole in the centre of the box

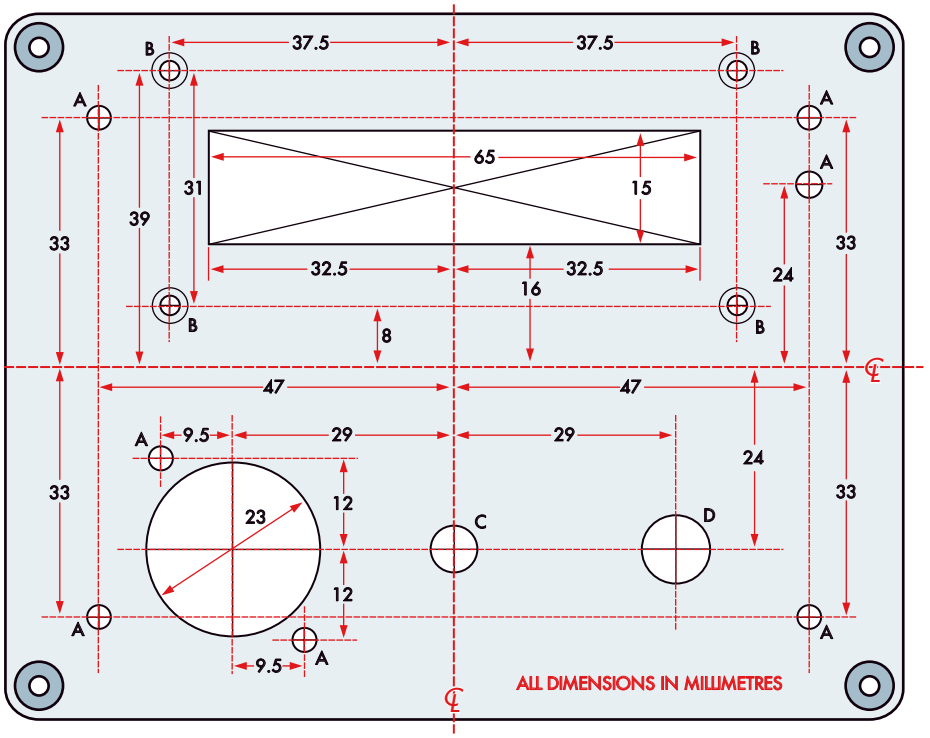


Fig.6: most of the holes that need to be made in the case go in the lid. Holes A are 3mm diameter, B are 2.5mm, C 6.5mm and D 9mm. You'll probably need a hole saw to cut the 23mm, although you could use a 20mm stepped drill bit and then enlarge to 23mm with a large tapered reamer. Note that holes "B" need to be countersunk after being drilled. See the text for suggestions on how to make the large rectangular cut-out.

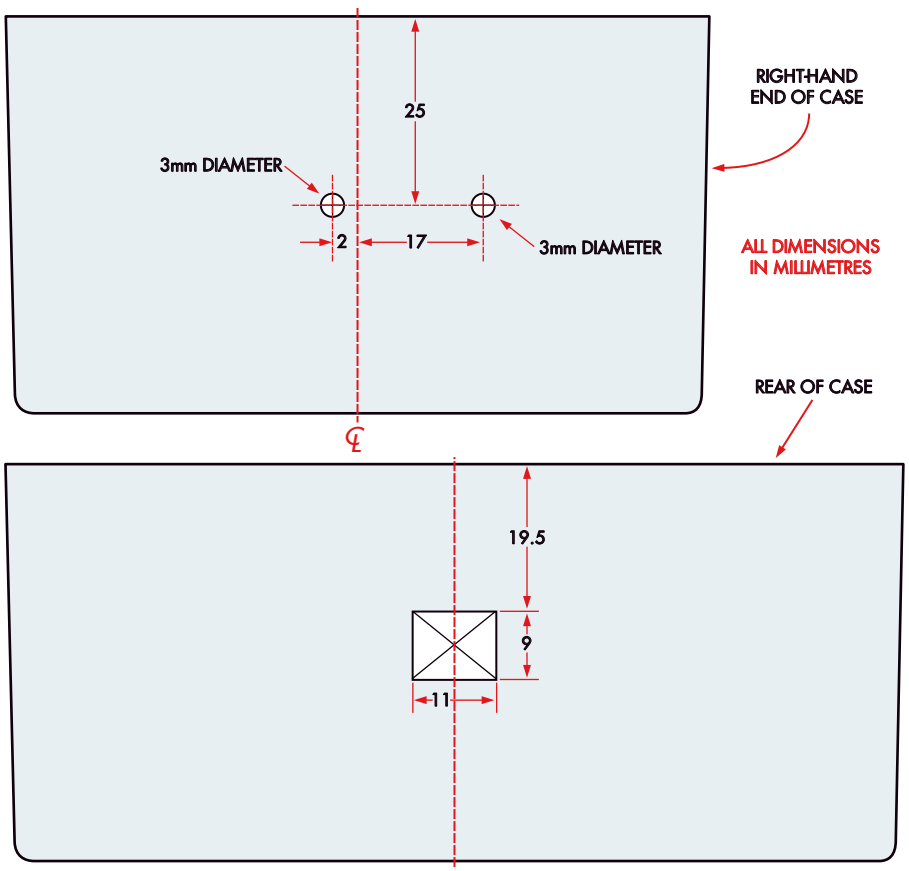
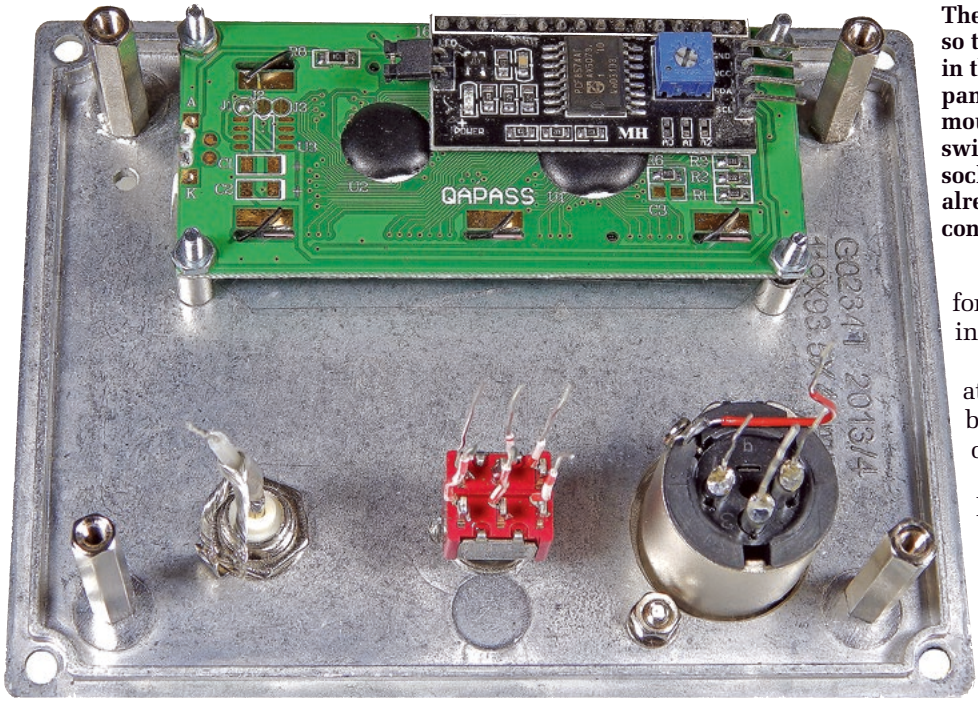


Fig.7: two holes need to be drilled in the side of the case to access the calibration potentiometer screws, while a small rectangular cut-out on one of the long sides provides access to the USB socket, both for power and optionally for logging measurements to a PC.



The pre-assembled display PCB mounts so that the LCD lines up with the cutout in the lid (which becomes the front panel). Here we also show the four mounting pillars and the input select switch along with the XLR and BNC sockets, with their connecting wires already soldered in place and ready to connect to the main PCB.

rear to allow access for the power/PC USB connector.

You'll find the location and sizes of all of these holes in the two drilling diagrams (Figs.6 & 7). Most of the holes are circular and can be drilled, although the 23mm diameter hole for XLR connector CON1 is best made using either a hole saw or by drilling a circle of small holes and then cutting between them using either a rat-tailed file or jeweller's saw.

The best plan for cutting the 65 x 15mm rectangular hole for the LCD screen is to drill a 6mm diameter hole inside each corner, to allow you to use a small metal-cutting jigsaw to cut along each side.

Then you can tidy up the edges using a small file.

For the rectangular hole in the rear of the box, I first drilled a 9mm diameter hole in the centre, then used jeweller's files to expand it out into the final rectangular shape.

Once all of the holes have been made, remove all burrs from the inside and outside of each hole using one or more small files.

As a final step in preparing the box for assembly, you should fit a professional-looking panel on the lid.

We have produced a front panel artwork for this project, which can be downloaded free of charge from the SILICON CHIP website (**www.siliconchip.com.au**) as a PDF file. Also on that website you will find various ideas for materials and procedures for making panels.

You can then print, laminate and attach it to the lid using thin double-sided adhesive tape or a smear of silicone sealant.

The final step is to cut out the holes in the dress front panel to match those in the lid itself, using a sharp hobby knife.

Final assembly

Glue an 80 x 40mm rectangle of 0.5mm thick clear plastic sheet to the rear of the lid, just behind the LCD window. This is to keep dust out and protect the LCD screen from accidental scratches. It can be cut from a clean takeaway container lid or similar.

Then mount the LCD screen to the underside of the lid using four 16mm-long M2.5 countersunk-head screws with four 9mm long untapped spacers and four M2.5 nuts, as shown in Fig.8. Next, fit XLR connector CON1 to the lid using two 9mm-long countersunk-head M3 screws with lock washers and nuts on the rear.

After this, fit BNC connector CON2 using its matching lock washer, solder lug and nut, then input selector switch S1.

To ensure that the switch is fixed

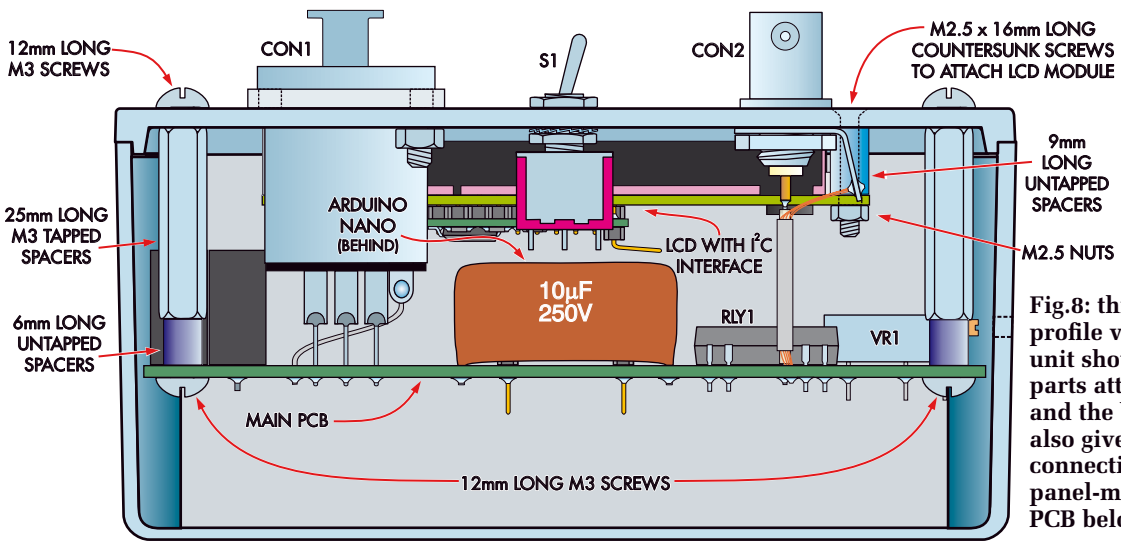
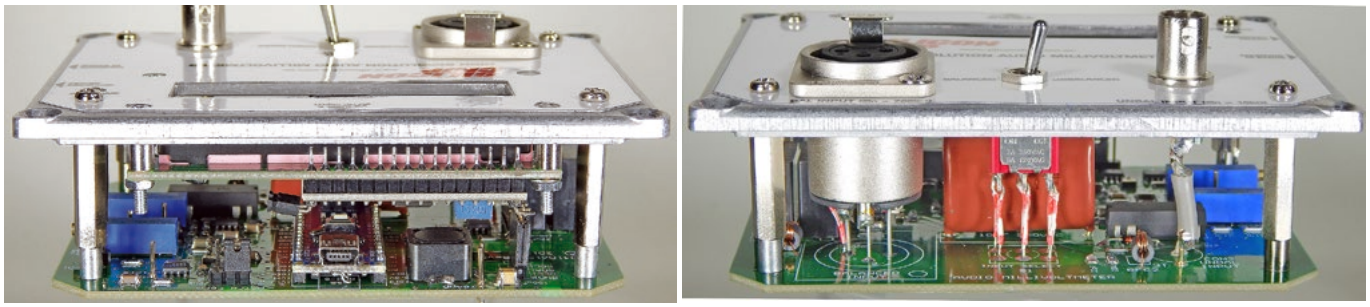


Fig.8: this 'cut-away' side profile view of the assembled unit shows how the various parts attach to each other and the back of the lid, and also gives you an idea of the connections needed from the panel-mounted parts to the PCB below.



"Left and right" views of the assembled project immediately before it is mounted in the diecast case. The input sockets and selector switch are all connected to the PCB via short lengths of either tinned copper wire or, in the case of the BNC socket (CON2), shielded cable. The photo at right compares with the diagram on the opposite page.

in place horizontally, you can drill a small blind hole in the rear of the lid to accept the spigot on the edge of the switch's flat washer.

Now up-end the lid/front panel and solder stiff wire leads to the rear lugs of CON1, CON2 and S1. These don't have to be very long; just long enough to pass down through their matching holes in the PCB when it's fitted.

The only one that needs special treatment is that for CON2, which should ideally be made using a 25mm length of shielded microphone cable.

Take care when separating the screen wires at each end, to prevent accidental shorts.

Once these extension leads have been fitted, you are ready to mount the PCB to the rear of the lid/front panel.

The PCB is mounted using four 25mm-long M3 tapped spacers, together with four 6mm long untapped spacers, as shown in Fig.8. First attach all four pairs of spacers to the corners of the PCB, using 12mm-long M3 screws passing up through the PCB and the untapped spacers and then into the 25mm tapped spacers.

The complete PCB-and-spacers assembly is then attached to the rear of the lid/front panel, using four 12mm-long M3 screws.

While doing this, ensure that the extension wires from CON1, S1 and CON2 pass through their matching holes in the PCB. And before you finally tighten up the screws, make sure that the body of LED1 is protruding through its matching hole in the front panel.

Now solder the ends of the extension wires from CON1, S1 and CON2 to their matching pads on the rear of the PCB.

If all has gone well so far, you should find that the pin ends of the 4-pin SIL header fitted to the end of the LCD module are now very close to those of the socket plugged into CON3.

You should only need to bend the module's header pins down slightly to meet the pins from CON3's socket, and then you can solder them together.

Your Meter is now complete, apart from the final fitting of the front panel assembly into the box.

But before you do this, it's a good idea to load the Meter's firmware sketch (program) into the Arduino Nano.

This is done using the Arduino IDE, running on a suitable PC, with the Meter connected to a USB port of the PC via a standard USB Type-A to mini Type-B cable.

Programming the Meter

The firmware program to be loaded into the Meter's Arduino Nano is called "AudiomVmeterMk2_sketch.ino", which you can download from

Ensuring that a low-cost Arduino Nano works reliably

There are Arduino Nanos . . . and there are Arduino Nanos!

During the development of this project, we discovered on two occasions that the 'El Cheapo' Arduino Nanos had started to malfunction.

In both cases, diode D1 in the Nano's power supply had 'blown' and changed into a high resistance, lowering the supply voltage to less than 2.8V.

This diode (an SS1 or an MBR0520) is not really required when the Nano is powered from USB. It's purely to protect the USB port of the PC when the Nano is powered via a higher voltage supply fed directly into its Vin pin.

Since the Nano and its associated circuitry (here, the Millivoltmeter) are always going to be powered from the USB connector, there's no reason why the diode can't be simply shorted out, to ensure reliable operation.

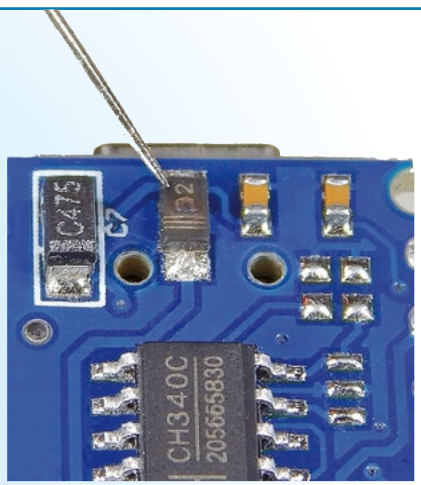
The problem is that the diode is fitted to the underside of the Nano's tiny PCB. This makes it quite inaccessible if the Nano has already been fitted to your Meter's main PCB. In fact, I had to virtually destroy the first Nano to remove it from the main PCB to get at the blown diode.

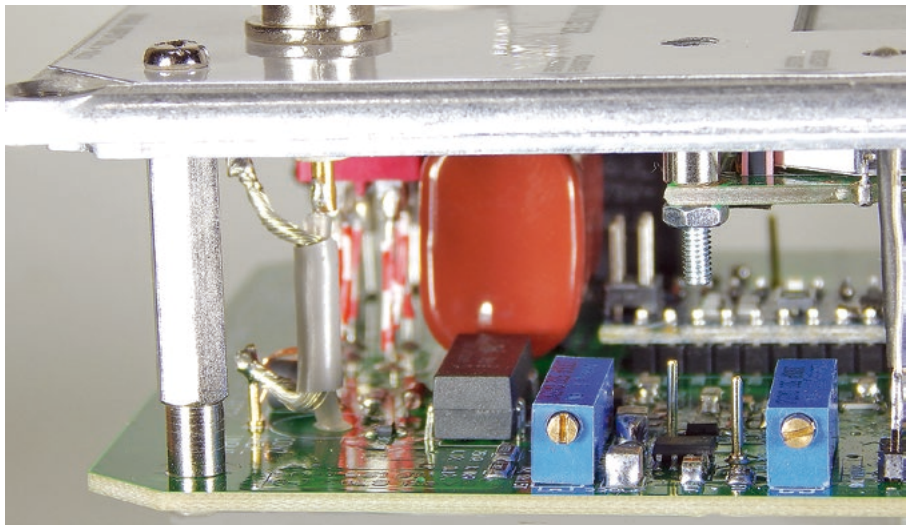
So we suggest that if you are going to be using a low-cost Nano in your Millivoltmeter, you should first short out D1 with a short length of wire, before mounting it on the main PCB.

This should ensure reliable operation and avoid the need for surgery at a later stage.

The photo at right shows where D1 is located, just below the Mini USB connector. The diode is usually marked "B2", although on the one in the photo it looks more like "D2" because there's a tiny crater in the middle of the B where the smoke came out.

It's quite easy to short out the diode with a short length of tinned copper wire, bent into a tiny inverted 'U'. If you use the same soldering iron you use to fit SMD components, it can be done quite quickly if you're careful. Just make sure that the wire link doesn't protrude upwards very far, or it might touch the top copper of your main PCB when the Nano is mounted on it.





This view of the right end of the PCB shows the two 15-turn trimpots, VR1 (left – 5kΩ) and VR2 (right – 50kΩ) which are used to set the HIGH range calibration and intercept adjust, respectively (see text). These pots line up with access holes drilled in the end of the case.

the SILICON CHIP website (www.siliconchip.com.au). Save it in a folder where you'll be able to find it later.

Now is also a good time to make sure that you have the latest Arduino IDE (integrated development environment) installed. If not, you can get it from www.arduino.cc/en/main/software This software allows you to compile and upload the code to the Arduino board.

Plug the meter into your PC, and its LCD backlight should light up, showing that the Meter is receiving 5V power.

Assuming you're running Windows, open Control Panel and select "System and Security" and then "Device Manager".

This should allow you to see the Virtual COM Port that the Meter has been allocated. It should also allow you to set the baud rate for communication with the Meter. Set it to 115,200 bps.

Now start up the Arduino IDE and load the sketch you downloaded earlier. In the IDE's Tools menu, set the Board selection to "Arduino Nano" and the Processor to "ATMega328P (Old Bootloader)", then set the COM Port to whichever one your Meter is connected to, as determined earlier.

Open the sketch and then in the Sketch menu, click on "Verify/Compile".

When you get the "Compiling Done" message, go to the Sketch menu again and this time click on "Upload". The compiled sketch should then be uploaded into the Nano MCU's flash memory.

After a few seconds, the Meter should start up, giving you a brief message on the LCD announcing itself. It will then start sampling from whichever input S1 is set to select.

At this stage, the Meter may not be giving sensible readings, since it has yet to be calibrated. But you can check the various DC voltages on the PCB test points.

For example, you should find a voltage very close to 5V between TP5V and TPGND, while the voltage at TP2.5V should read 2.500V with respect to TPGND.

If those check out, you can now install your meter in its box, by lowering it in and then screwing the lid with the four M4 countersunk screws supplied with it.

Calibration

For accurate results, your Meter must be calibrated.

You'll need access to an audio oscillator or a function generator, together with a DMM capable of making accurate and reasonably high-resolution AC voltage measurements in the range from 500mV to 10V (RMS).

Power up the audio oscillator or function generator and set it to provide a 1kHz signal with an amplitude of 600mV RMS (1.697V peak-to-peak).

Check this level using your DMM, and adjust the generator if necessary. Then power up the Millivoltmeter and connect the oscillator's output signal to the Meter's unbalanced input (CON2), with S1 set appropriately.

After a few seconds, the Meter should show a stable reading in both millivolts and dBV, with the legend "(L)" at lower right. This indicates that the Meter has switched to its lower range.

At this stage, the reading will probably differ a little from the correct value of 600mV and -4.437dBV.

So use a small screwdriver or alignment tool to adjust trimpot VR2 (INTERCEPT ADJUST), to bring the reading as close as possible to that correct value. This calibrates the Meter's low range.

The next step is to calibrate the Meter's high range. Change the output level of the audio oscillator or function generator to 10.000V RMS (28.28V peak-to-peak), checking this using your DMM again.

If your oscillator or function generator can't provide an output that high (which is quite common), you may have to use a small amplifier to boost its output.

An amplifier capable of doing just that, very accurately, is described starting on page 92 of this issue.

Now connect the oscillator's output signal to the Meter's unbalanced input (CON2) again, and after a couple of seconds, the Meter should display a new reading.

This time, the legend at the end of the lower line should read "(H)", to show that it has now switched to the higher range.

The new reading is likely to be fairly near the correct value of 10.000V and 20.00dBV, but not spot-on. Correct it by adjusting trimpot VR1 (CALIBRATE HI RANGE).

Once this has been done, your new Digital Millivolt/Voltmeter is calibrated and ready for use.

Logging measurements

All you need to do to log measurements to your PC is open up the Arduino Serial monitor, using the same settings as described above for programming the Nano.

With the unit connected to your PC, each time it takes a measurement, it will also be written to the serial monitor.

When finished, you can save the log for later analysis (eg, using a spreadsheet program). SC

your DIY AV destination

hardcore electronics by **jaycar**

think. possible.

On sale 24 September to 23 October, 2019

BLUETOOTH® 5.0

Audio transmitter & receiver

with optical output

Multi-directional. Can stream audio to or from Bluetooth® device to play on your stereo system etc. Supports Bluetooth® 5.0 technology that allows two Bluetooth® devices to be paired at the same time. AA2112

- DUAL BLUETOOTH® STREAMING
- RECHARGEABLE BATTERY

ONLY **$99.95**

NEW

Bluetooth® 5.0 explained

Bluetooth® 5.0 offers many benefits over earlier versions: Lower power consumption (for longer battery life), twice the data rate (up to 2Mbps), 4 x the range (up to 240m) and 8 x the broadcast messaging capability of Bluetooth® 4.2.

That's not all, with Bluetooth® 5.0 Dual Audio, you can stream music to two different speakers at the same time! But to benefit from all the new Bluetooth® 5.0 features, you need to have both devices compatible with the new standard.

Quality AV equipment

ONLY **$89.95** 4K UHD

NEW

CONCORD

HDMI audio extractor

Extracts the audio stream from a HDMI signal so you can listen to the audio through your home theatre system, amplifier or active speakers. Outputs: TOSLINK optical, digital coaxial & analogue 3.5mm stereo audio. AC5030

ONLY **$179** 4K UHD

NEW

CONCORD

4-Way HDMI splitter with downscaling

Connects a single HDMI source to four HDMI displays and downscales 4K signals to 1080p. Analogue and digital audio output. AC5004

ONLY **$249** 4K UHD

NEW

CONCORD

4K HDMI Cat5e/6 extender

Send 4K signals from a set top box, media player, or other video source to another room up to 50m away over an ethernet Cat6 cable. High-Dynamic-Range (HDR) video support. AC5020

JUST **$39.95**

NEW

Audio mixer with Bluetooth® technology

Compact and rechargeable, ideal for street busking, outdoor parties, etc. . 3.5mm Auxiliary input & output. 6.5mm Microphone input. 1500mAh rechargeable battery. AM4230

JUST **$119**

NEW

2 x 15WRMS compact stereo amplifier with Bluetooth® technology

Stream music via Bluetooth® with this compact stereo amplifier. RCA line input. Extruded aluminium enclosure. 12VDC powered. 2x15WRMS. AA0522

FROM **$229**

SAVE UP TO $100

Ultra long HDMI fibre optic cables

Uses both fibre optic and copper cores to transmit Ultra HD 4K signals. Supports up to 6Gbps per channel (18Gbps). Lightweight and flexible.

50m WQ7496 **WAS $299 NOW $229 SAVE $70**
100m WQ7498* **WAS $449 NOW $349 SAVE $100**
**Special order only.*

ONLY **$229**

NEW

PORTABLE 5.8GHZ WIRELESS 1080P

HDMI AV sender

Connect your HDMI device without wires! Transmit crystal clear 1080p signals up to 15m wirelessly. Includes two USB power cables and two HDMI extensions cables. AR1901

NOW **$49.95**

SAVE $10

4K UHD

4-Input HDMI 2.0 switcher

Connect up to 4 HDMI inputs, and feed them to your flat-screen, projector, or any other HDMI display. Remote control included. AC1745 **WAS $59.95**

NOW **$29.95**

SAVE $10

Headphones with Bluetooth®

Stream music using Bluetooth® technology, freeing you from cables. Works as a handsfree device too. Built-in microphone. AA2134 **WAS $39.95**

2 FOR **$29.90**

SAVE $10

3" 15WRMS replacement speakers

Suitable for use in home theatre, surround speakers, computer multimedia speakers etc. 8Ω. AS3034 **$19.95ea**

Also Available:
1" 1WRMS AS3030
2 FOR $18.90 $12.95ea
2" 10WRMS AS3032
2 FOR $26.90 $17.95ea

See www.digitalradioplus.com.au for more information on DAB reception areas.

Tech Talk: DAB radio

Digital radio broadcasting (DAB+) is a free-to-air radio service, operating on a higher frequency band than FM. It offers clear noise-free quality sound as well as on-screen program information plus artist and track titles. Some DAB+ receivers also provide pause and rewind functions, as well program schedules, local weather and information concerning station events and activities. DAB+ simulcasts most of the existing AM and FM stations plus approximately 100 new Digital-Only radio stations.

You'll never again be bored listening to the same old FM and AM radio stations; with the many more stations available on digital radio you're sure to find your favourite niche, such as the relaxing Chill Out Buddha Hits, iHeart 90's, KIX Country, MMM Greatest Hits and many others. Maybe you prefer sports, news and talkback radio; you can tune in to ABC Extra, ABC Kids Listen, TAB Live, SkySportsRadio, or Macquarie Sports Radio, and much more.
Note: Currently DAB+ digital radio broadcasts are available only in major Australian cities: Sydney, Melbourne, Brisbane, Perth, Adelaide, Canberra, Darwin and Hobart.

FROM **$59.95**

Portable DAB+ & FM radios

Modern looking pocket-sized radio that receives DAB+ digital radio and conventional FM with PLL synthesized receiver for a high level of stability.
DAB+ and FM Radio AR1690 **$59.95**
DAB+ and FM Radio with Bluetooth® Technology AR1692 **$99.95**

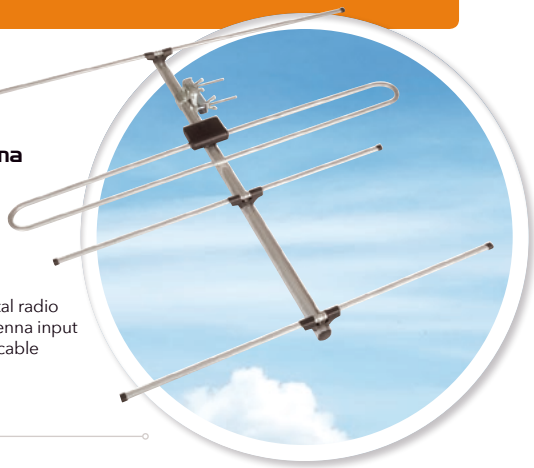
- Radio Data Stream (RDS) function for receiving digital information
- 20 radio presets
- Backlit LCD display
- Clock and alarm with sleep mode
- 3.5mm Stereo headphone socket

ONLY **$39.95** NEW

DAB+ outdoor antenna

If you live on the fringe or an area where the digital DAB+ radio reception isn't the best, then this antenna will help ensure uninterrupted listening time.
- Improve signal to your digital radio
- Suits digital radios with antenna input
- Supplied with 8.5m F-Type cable
- Mounting bracket included

LT3159



JUST **$14.95**

• VERY GOOD AT RECEIVING WEAK STATIONS

AM/FM transistor radio

- AM/FM selection (mono only)
- Simple mechanical tuning
- Earphone socket
- Uses advanced signal processing chip (ZK8829 **$7.95** sold seperately)
- Requires 2 x AAA batteries
- 55(W) x 89(H) x 19(D)mm

AR1458

JUST **$24.95**

Multiband FM/MW/SW pocket radio

- FM/MW/SW1-7 bands and with DSP (digital signal processing)
- Dynamic Bass Boost System
- Clock and alarm function
- Earphone socket
- Requires 3 x AAA batteries
- 110(W) x 70(H) x 28(D)mm

AR1736

JUST **$34.95**

AM/FM/SW rechargeable radio with MP3

- Tri-band AM/FM/SW with built-in MP3 player
- Supports USB and microSD card (32GB max)
- Earphone socket
- Rechargeable Li-ion battery supplied
- 114(W) x 70(H) x 25(D)mm

AR1721

PHASE-LOCKED LOOP FUNCTION

NOW **$69.95**

SAVE $10

World band radio with PLL

- Multiband AM/FM/SW/LW/AIR bands
- Phase-Locked Loop (PLL) for stable reception
- Air squelch function
- 500 pre-set stations
- Sleep function up to 120min.
- Manual, auto, or pre-set station search
- Requires 2 x AA batteries
- 120(W) x 75(H) x 30(D)mm

AR1733 **WAS $79.95**

LISTEN TO CB, HAM RADIO & MORSE CODE

NOW **$109**

SAVE $20

Compact World band radio with PLL & SSB

- FM/MW/SW/LW/AIR bands
- Phase-Locked Loop (PLL) for stable reception
- Single Side Band (SSB) to listen to morse code etc.
- 1000 pre-set stations
- Expandable antenna
- Requires 4 x AA batteries
- 150(W) x 95(H) x 30(D)mm

AR1780 **WAS $129**

GREAT SOUND

NOW **$129**

SAVE $20

Large world band radio with PLL

- AM/FM/SW1/SW2/SW3 bands
- Phase-Locked Loop (PLL) for stable reception
- Receives international SW broadcast
- Large telescopic antenna
- 50 pre-set stations
- Speaker 5W/4 ohms
- Mains (supplied) or battery (6 x D required) operated
- 310(W) x 195(H) x 100(D)mm

AR1748 **WAS $149**

your destination for
sound & signal

choose the right TV antenna for your needs

There are many factors which influence which antenna is right for you. Do you know your phased array from your VHF? Don't worry, our friendly team can help guide you with the perfect antenna and all required hardware! For more information: www.jaycar.com.au/tvantenna

NOW
$39.95
SAVE $5

30m antenna cable
- Belden RG6 coax
- Foxtel approved

WB2014 **WAS $44.95**

ONLY
$119
Kingray

VHF/UHF masthead amp
High gain with LTE/4G filters to compensate for redistribution of broadcast frequencies. LT3251
See website for full details.

FROM
$32.95
SAVE 25%

IDEAL FOR REGIONAL AREAS
43 Element UHF antenna
Built-in LTE/4G filter. 4-5 bands. Channels 21-69.
LT3181 **WAS $44.95 NOW $32.95 SAVE $12**

IDEAL FOR METROPOLITAN AREAS
6 Element VHF Yagi antenna
Heavy duty. 3 band. Channels 6-12.
LT3153 **WAS $89.95 NOW $64.95 SAVE $25**

NOW
$24.95
SAVE $15

Hex ratchet crimping tool
For crimping F, N, BNC, TNC, UHF, ST, SC & SMA connectors.
TH1833 **WAS $39.95**

ONLY
$14.95

4G/LTE filter for digital TV reception
Blocks unwanted signals. Waterproof. LT3062

FROM
$7.95
NEW

Kingray
Foxtel® approved splitters
RF screening to reduce interference. >100dB RF shielding. 5-2400MHz.
2-Way LT3069 **$7.95**
4-Way LT3071 **$12.95**

DIGITAL READY
ONLY
$29.95

IDEAL FOR RENTERS
Slim-type indoor antenna with amplifier
Fitted with an LTE/4G filter which protects your TV from mobile broadband interference. LT3206

NOW
$49.95
SAVE $15

IDEAL FOR TRAVELLERS
UHF/VHF outdoor antenna
Digital ready with signal amplifier and built-in motor to rotate the antenna for the best signal. LT3143 **WAS $64.95**

Bring your old speakers back to life

JUST
$19.95

25mm titanium dome tweeter
Produces very crisp and clear high frequencies. 50WRMS. 8Ω. CT2007

FROM
$54.95
SAVE UP TO $20

In-ceiling 2 way speakers with tweeter
Excellent audio quality compared to traditional PA speakers. Combination of coaxial woofer with dome tweeter. Sold as a pair.
5.25" 30WRMS CS2451 **WAS $64.95 NOW $54.95 SAVE $10**
6.5" 40WRMS CS2453 **WAS $79.95 NOW $64.95 SAVE $15**
8" 50WRMS CS2455 **WAS $99.95 NOW $79.95 SAVE $20**
Can be easily painted black with a can of acrylic spray.

2 FOR
$34.90
SAVE $15

4" paper cone woofers

Excellent for replacement or for new speaker design construction. Equipped with strong steel frame baskets, high power magnet and voice coils. CW2190 **$24.95 ea**
ALSO AVAILABLE:
5" 50WRMS CW2192 **2 FOR $39.90 $29.95 ea**
6.5" 60WRMS CW2194 **2 FOR $49.90 $34.95 ea**
8" 90WRMS CW2196 **2 FOR $59.90 $39.95 ea**
10" 225WRMS CW2198 **2 FOR $99.90 $64.95 ea**
12" 225WRMS CW2199 **2 FOR $119.90 $79.95 ea**

NOW
$24.95
SAVE $10

60W speaker attenuator wall plate
Control the volume of speakers locally. 6-step volume control. Suitable for 4Ω, 8Ω or 16Ω speakers.
AC1751 **WAS $34.95**

FROM
$12.95

30m Roll speaker cables
Light Duty WB1703 **$12.95**
Heavy Duty WB1709 **$32.95**
Extra Heavy Duty WB1713 **$74.95**

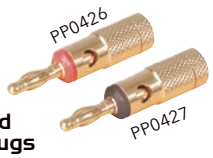
FROM
$9.95
SAVE $5

Sound deadeners
Self-adhesive and easily moulded. 330mm wide.
Foam AX3662
WAS $14.95 NOW $9.95 SAVE $5
Butyl AX3687
WAS $29.95 NOW $24.95 SAVE $5
Butyl/Foam Combo AX3689
WAS $29.95 NOW $24.95 SAVE $5

FROM
$14.95

"Speakon" loudspeaker connectors
4 pole with locking ring. Solderless termination.
In-line PP1090 **$14.95**
Right Angle PP1091 **$19.95**

ONLY
$4.95 ea



Gold plated banana plugs
Designed for monster type speaker cable. Side entry hole, with finger screw locking action.
Red PP0426 **$4.95**
Black PP0427 **$4.95**

PROJECT:
Wi-Fi LED lighting strip

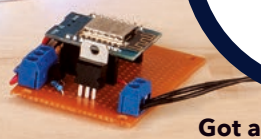
Want to decorate your kitchen, bar or living area with cool lighting effects?
This project will show you how to construct, program and connect your Arduino based controller and LED strip light. Powered by 12VDC and controlled via a Homebrew Wi-Fi application (see our website for more details).

SKILL LEVEL: Beginner
TOOLS: Soldering Iron, Scissors, Knife

SEE STEP-BY-STEP INSTRUCTIONS AT:
www.jaycar.com.au/wifi-led-lightingstrip

1 × RGB LED Flexible Strip Lighting Kit with Effects	SL3954	**$89.95**
1 × Wi-Fi Mini Main Board	XC3802	**$24.95**
1 × Ultra Mini Experimenters Board	HP9556	**$4.95**
1 × 7805 +5V 1A Voltage Regulator TO-220 Case	ZV1505	**$1.85**
1 × 3-Way PCB Mount Screw Terminals 5mm	HM3173	**$1.55**
1 × 2-Way PCB Mount Screw Terminals 5mm	HM3172	**$1.20**
1 × 1µF 25VDC Tantalum Capacitor	RZ6627	**75¢**
1 × 2N7000 N-Channel FET	ZT2400	**75¢**
1 × 1kΩ 1W Carbon Film Resistors - Pk2	RR2774	**48¢**
1 × 10µF 25VDC Electrolytic RB Capacitor	RE6070	**35¢**

NERD PERKS BUNDLE DEAL
$99
SAVE 20%
KIT VALUED AT $126.78



A big shout out to...
ADAM
from Hammond Park, WA who received a $100 gift card for sharing his brilliant project idea!

Got a great project idea?
Upload your idea at projects.jaycar.com
If we produce or publish your electronics, Arduino or Pi project, we'll give you a complimentary **$100 gift card.**

TEAM UTS 2019 CHAMPIONS

A look back at our recent Battle of the Uni's "Tech Wars 2019" - the inaugural tech-maker University challenge.
We put @USYD and @UTS to the ultimate 48 hour project battle.
THEIR CHALLENGE?
SOLVE AN EVERYDAY PROBLEM THROUGH TECHNOLOGY.
The battle ran from Wed 14th - Fri 16th Aug at the Makerhub at our flagship Broadway store. Check out the event here: www.jaycar.com.au/makerhub

ONLY
$3.95

Active buzzer module
The easy way to add sound to your project. Hook up a digital pin and ground, and use the tone() function to get your Arduino* beeping. XC4424

ONLY
$4.95

2 x 3W amplifier module
For more volume than XC4424, connect this module to drive a small speaker (up to 3W). The high efficiency Class D amplifier runs happily off 5V. XC4448

ONLY
$7.95

Microphone sound sensor module
Great for any project that needs to detect sounds. Includes both analogue (for waveform) and digital output with adjustable threshold for simple sound detection. XC4438

FROM
$3.50
AS3002

Add sound to your project
All purpose replacement speakers for your next project. 8Ω.

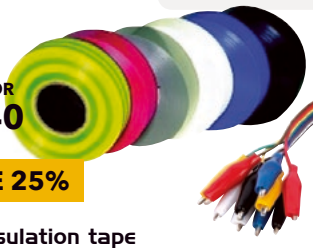
27mm 0.25W	AS3002	**$3.50**
40mm 0.25W	AS3004	**$3.95**
57mm 0.25W	AS3000	**$4.50**
76mm 1W	AS3006	**$4.95**
50 x 90mm 5W	AS3025	**$6.95**

ONLY
$3.95
Coin not included.

Mini buzzer 5-15V
This handy little solid state buzzer operates between 5-15VDC. Used in many applications. Current consumption 40mA max. Sound level: 79dB/1mt. AB3452

NOW
$29.95
SAVE $14

Breadboard - 1660 tie points
400 distribution holes / 1280 terminal holes. Mounted on a metal plate. 3 banana terminals. Rubber feet. 157(W) x 237(H)mm. PB8816 **WAS $43.95**



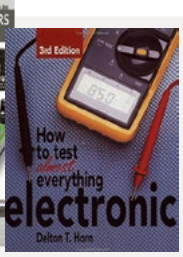
ANY 2 FOR
$4.40
SAVE 25%

PVC insulation tape
5 colours available. 18mm wide. 20m length. NM2801 - NM2807 **$2.95 ea**

ONLY
$9.95

Jumper lead set
Each cable consists of a pin to alligator clip. Multi-colour. 20cm long. 10pcs. WC6032

BM7144
ONLY
$79.95



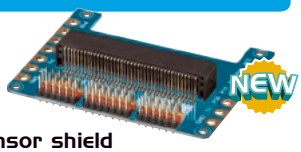
BM7200
ONLY
$49.95

Mastering microcontrollers helped by Arduino
Theory is put into practice on an Arduino board using the Arduino programming environment. Soft cover. 380 pages. BM7144

How to test almost everything electronic
Everything from setting up a test and work area to using the most important types of test equipment - multimeters, oscilloscopes, signal generators, etc. Soft cover. 326 pages. BM7200

BONUS GIFT!
SPEND OVER $30 ON THIS PAGE
(TH2510 VALUED AT **$4.95**)
Limit ONE per transaction.

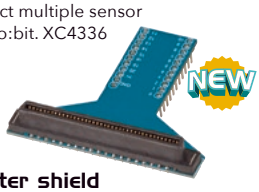
BEGINNER: micro:bit



ONLY **$14.95**

micro:bit sensor shield

Enables you to connect multiple sensor modules to your micro:bit. XC4336 *Due early October.*



ONLY **$14.95**

micro:bit t-adapter shield

This T-Type breakout board is for accessing micro:bit pins through a breadboard, in order to create additional circuits. XC4334 *Due early October.*

ONLY **$19.95**

micro:bit breakout board with 2 x AA battery holder

Provides an independent 3V power supply to your micro:bit project and enables you to interface to other hardware. XC4330 *Due early October.*

Due early October
ONLY **$23.95**

micro:bit prototype board

Supplied with 400-hole breadboard, designed to break out all IO pins on your micro:bit for you to create additional circuits and hardware. XC4332

ONLY **$34.95**

micro:bit go

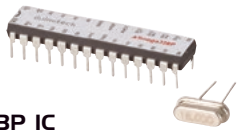
DEVELOPMENT BOARD KIT

Pocket-sized computer that you can code, customise and control to bring your digital ideas, games and apps to life. Completely programmable via Microsoft MakeCode or MicroPython. Includes cable and battery pack.

- Bluetooth® connectivity
- 5 x 5 LED display

XC4320

INTERMEDIATE: Arduino®



ONLY **$12.95**

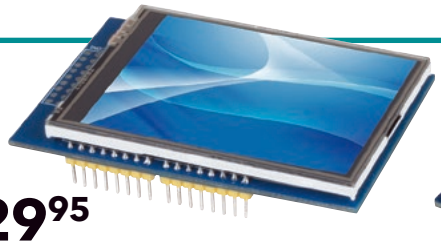
ATMEGA 328P IC

Build your very own customised Arduino® compatible projects. Comes with UNO bootloader and 16MHz crystal oscillator. ZZ8727

FROM **$4.95**

Clear acrylic enclosures

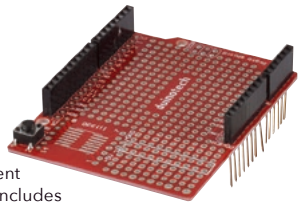
Protect your Arduino board against damage, dust and scratches. Pre-drilled.
Suits UNO XC4406 **$4.95**
Suits MEGA XC4408 **$6.95**



JUST **$29.95**

240 x 320 LCD touch screen

Large, colourful touch display shield which piggy-backs straight onto your UNO or MEGA. Fast parallel interface. microSD card slot. Resistive touch interface. XC4630



JUST **$15.95**

Prototyping board shield

This stackable shield makes semi-permanent prototyping simple. Includes reset button. XC4482

ONLY **$49.95**

Duinotech MEGA board

Our most powerful Arduino® compatible board. Boasting more IO pins, more memory, more PWM outputs, more analogue inputs and more serial ports.

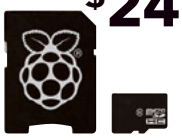
- 256KB program memory
- ATMega2560 Microcontroller

XC4420

ADVANCED: Raspberry Pi

16GB NOOBS SD card

Comes pre-loaded with NOOBS software for easy installation of Raspbian operating system. Full size SD card adaptor included. XC9030



ONLY **$24.95**

ONLY **$12.95**

GPIO expansion kit

Colour coded rainbow ribbon cable, all 40 GPIO pins are broken out to a header which can be plugged straight into a breadboard. Clearly labelled header. XC9042

FROM **$29.95**

Touch screens

Compact, portable display to connect directly to your Pi. HDMI input and includes a resistive touch interface.
2.8" 320x240 Resolution XC9022 **$29.95**
5" 800x480 Resolution XC9024 **$99.95**
7" 1024x600 Resolution XC9026 **$159**

JUST **$24.95**

5MP camera

Connects directly to the camera connector on the Raspberry Pi. Supports up to 1080p video, up to 2592x1944 pixel images. XC9020

JUST **$84.95**

SINGLE BOARD COMPUTER

Raspberry Pi 3b+

Tiny credit card size computer.

- 1.4GHz 64-bit quad-core processor
- Dual Band 2.4GHz & 5GHz Wireless LAN
- Bluetooth® 4.2 technology with BLE
- Faster processing and networking
- Supports Power-over-Ethernet (with separate PoE HAT)

XC9001

your destination for the best rewards & perks:

love jaycar? you're going to love our rewards!

Shop
In store & online

Earn points
For dollars spent
1 point = $1

Get rewards
eCoupons for future shops in store
200 points = $10 eCoupon

+ Perks
offers, event invitations, account profile and more...

Long distance VGA balun with audio

Connect your computer or media player with VGA output to a VGA monitor or projector up to 30m^ away using bonus Cat5e lead. AC1671 **REG $129**
^Capable of distances up to 300m

CLUB OFFER

FREE* 30M CAT5E LEAD
YN8208 **VALUED AT $37.95**
**Valid with purchase of AC1671*

USB MIDI* interface

Connects your older MIDI-equipped musical instrument that has 5-pin DIN to your computer via USB.
XC4934 **REG $29.95**
**MIDI - Musical Instrument Digital Interface*

CLUB OFFER
$19.95
SAVE $10

CLUB OFFER
$199
SAVE $69.95
VALUED AT $268.95

Reversing camera with 9" LCD monitor

1 × 9" High Resolution Monitor
QM3874 **REG $219**
1 × Flush Mount 12V camera
QC3530 **REG $49.95**

CLUB OFFER SAVE **35%**

Double 4-speed gearbox

2 x FA-30 type 3V motors.
YG2741 **REG $23.95 CLUB $14.95**

CLUB OFFER SAVE **20%**

Headlamp kit with luxeon Z ES LEDs

40W 3000 lumens H4 high/low. 12/24V.
SL3524 **REG $169 CLUB $129**

CLUB OFFER SAVE **25%**

CCTV video & power cable

18m. BNC terminated.
WQ7279 **REG $19.95 CLUB $14.95**

CLUB OFFER SAVE **30%**

1m Armoured Lightning™ USB cable

Stainless steel. Durable.
WC7754 **REG $29.95 CLUB $19.95**

CLUB OFFER SAVE **20%**

Thermocouple thermometer

2 Input. Max and hold function.
QM1601 **REG $94.95 CLUB $74.95**

CLUB OFFER SAVE **25%**

7-pcs Screwdriver set

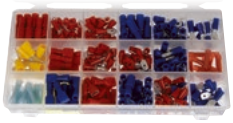
Durable. Fully insulated.
TD2022 **REG $34.95 CLUB $24.95**

CLUB OFFER SAVE **30%**

LED pack - 100pcs

3mm and 5mm LEDs of mixed colours.
ZD1694 **REG $29.95 CLUB $19.95**

CLUB OFFER SAVE **25%**



QC crimp connector pack

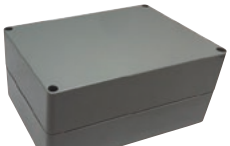
Bullet, ring, fork, spade and joiners in various sizes and colours. 300pcs.
PT4536 **REG $39.95 CLUB $29.95**

CLUB OFFER SAVE **25%**

Programmable interval timer module

12VDC. Low current drain.
AA0378 **REG $39.95 CLUB $29.95**

CLUB OFFER SAVE **30%**



Sealed ABS enclosure

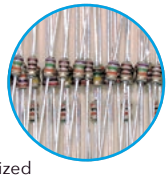
171 x 121 x 80mm, dark grey.
HB6129 **REG $21.95 CLUB $14.95**

CLUB OFFER SAVE **50%**

CD/cassette adaptor

Supplied with 1m lead and 3.5mm stereo plug. AR1760 **REG $16.95 CLUB $8.45**

CLUB OFFER SAVE **20%**



Resistor pack

1/4W 5% miniature sized carbon film. 1700pcs.
RR2000 **REG $32.95 CLUB $24.95**

---

exclusive club offer

15% OFF
HDMI LEADS & ADAPTORS*
**See T&Cs for details*

your club. your perks!

Check your points & update details online.
Login & click "My Account"
Conditions apply. See website for T&Cs

your destination for

workbench essentials

1. F-type removal tool
- Insert or unscrew F-type or BNC connector
- Comfortable grip
- Carbon steel
- 255mm long

TD2000 **WAS $14.95**

2. 80W slimline lab power supply
- 0-16V/5A, 0-27V/3A, 0-36V/2.2A
- Powerful and compact design
- Constant current and voltage options
- Includes banana to alligator clamp leads

MP3842 **WAS $149**

3. Speaker polarity tester with tone generator
- Sinewave tone generator, speaker polarity and RCA cable tester
- Output range: 0V-8V
- RCA or alligator clips
- Requires 1 x 9V battery (SB2423 **$3.95**)

AA0414 **WAS $29.95**

4. Roadies cable tester
- Tests speakon, TRS, DIN, XLR, RCA, USB & RJ45 cables
- Metal construction
- Requires 1 x 9V battery (SB2423 **$3.95**) AA0405 **WAS $79.95**

5. ABS instrument case
- Robust case for test equipment, camera gear, etc.
- Includes a purge valve for an airtight seal
- 330(W) x 120(H) x 280(D)mm

HB6381

6. Pro sound level meter with calibrator
- Ideal for any evidence-based noise testing
- Includes a calibrator to verify results
- A & C weighted
- Compliant with type 2 (Class 2) standards

QM1592 **WAS $379**

FLASHFORGE

SIMPLE. SMART. ACCESSIBLE.

Adventure 3
3D printer

Control print jobs via the cloud using flashcloud and/or polar cloud. Compact structure with no angular design. Ready to use and no levelling printing. Removable, heatable and bendable plate.
- Low noise operation
- Automatic filament feeding
- Print up to 150(L) x150(W) x150(H)mm

TL4256 **WAS $899**

Flashforge PLA filament available in 600g or 1kg of various colours. FROM $24.95

NOW $799

SAVE $100

- 2.8" TOUCHSCREEN PANEL
- WI-FI, USB & ETHERNET CONNECT
- BUILT-IN CAMERA FUNCTION

3D printing toolkit
Includes commonly required tools that you need to service your printer or to unclog a blocked print head.
TD2132

ONLY $49.95

BACK BY POPULAR DEMAND!

JUST $9.95

Third hand PCB holder tool with alligator clips
Ideal aid for any application where a third hand is needed i.e PCB assembly, soldering work etc.Heavy cast iron base. Movable arms. TH1982.
Due early October.

JUST $24.95

Wire draw fish tape
Draw wire and cable through wall cavities or conduit. Easily retracts. 15m long. TH2350

JUST $89.95

Rechargeable lithium-ion soldering iron set
Solder without mains power or butane gas. Comes with 30W/12W tips, hot knife, solder & sponge. Up to 50 minutes operation. LED light. ESD safe. TS1545

NOW $29.95

SAVE $10

Ratchet crimping tool
Strong, heavy duty tool for crimping F-type CAT-V connectors onto RG6 or RG59 coax. TH1831 **WAS $39.95**

NOW $24.95

SAVE $5

Compression crimping tool for F-type plugs
Accurately positions the plug, and a spring-loaded clamp holds the cable in position. 143mm long. TH1803 **WAS $29.95**

JUST $11.95

F connector seating tool
This 3 way tool assists in the connection of F type connectors. TH1883

JUST $16.95 ea

Liquid electrical tape
Seals and protects electrical connections. 28g tube.
Black NM2836
Red NM2838

JUST $14.95

Gaffer tape - 25m
Waterproof. Very adhesive and strong. 48mm wide x 25m roll. Black. NM2810

JUST $8.95

UGlu industrial glue strips
Make quick repairs without tools. Instant bond, permanent hold. Waterproof. 8 strips. NA1522

JUST $7.95

WD40 150g spray can
Multi-use. Stops squeaks. Cleans and protects. NA1029

clearance

save $100

NOW
$199
SAVE $100

Dual input 20A DC/DC multi-stage battery charger
Keeps your 12V auxiliary battery topped up, from either main engine power when driving (either 12V or 24V systems), or solar when available. Fully automatic. MB3683 **WAS $299**

NOW
$199
SAVE $100

1080p PTZ bullet camera
Supports AHD, TVI, CVI, CBVS (analogue). Pan, tilt & zoom control via existing DVR. IR night vision. IP66 rated. QC8676 **WAS $299**

Check in store or online for compatible cameras

NOW FROM
$299

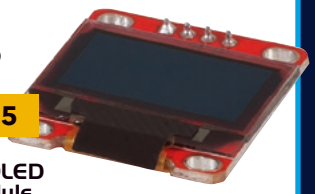
Techview AHD DVRs
Support the latest HD analogue AHD, TVI & IP cameras. View live footage on a Smartphone via free app. HDD included.
8 Channel 1080p QV3157
WAS $499 NOW $299 SAVE $200
16 Channel 3MP QV3159
WAS $749 NOW $499 SAVE $250
In-store only

SAVE UP TO **$250**

50% off

HALF PRICE
$12.45
SAVE $12.50

HDMI to VGA & stereo audio converter
Convert your HDMI output to VGA and stereo audio outputs. Supports up to 1080p resolution. AC1784 **WAS $24.95**



HALF PRICE!
$14.95
SAVE $15

128 x 64 OLED display module
Monochrome graphics with wide viewing angle and I²C interface. XC4384 **WAS $29.95**
In-store only

up to 30% off

NOW
$29.95
SAVE $10

4-door power lock kit
Low cost central locking kit, so when you unlock the drivers door the other three doors automatically unlock.
LR8812 **WAS $39.95**

AC600 outdoor Wi-Fi extender
Functions as Wi-Fi repeater, access point, or router. Dual band for speed up to 433Mbps. Single PoE connection. Weatherproof.
YN8349 **WAS $119**

NOW
$89
SAVE $30

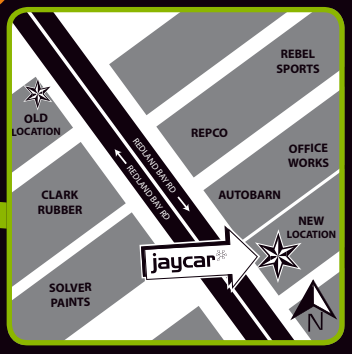
NOW
$59.95
SAVE $30

12/24V 30A PWM* solar charge controller
Detects 12V or 24V inputs automatically and can be left on permanently. LCD backlit display. Dual timer. MP3754 **WAS $99.95** *In-store only.*
**PWM - Pulse Width Modulation*

NOW
$9.95
SAVE $5

PoE power splitter
Splits the PoE into a regular ethernet, and 12VDC plug. Allows you to power IP cameras.
YN8414 **WAS $14.95**

TERMS AND CONDITIONS: REWARDS / CLUB MEMBERS FREE GIFT, % SAVING DEALS, & MEMBERS OFFERS requires ACTIVE Jaycar Rewards / membership at time of purchase. Refer to website for Rewards / membership T&Cs. IN-STORE ONLY refers to company owned stores and not available to resellers. Page 4: Club Project Kit: Wi-Fi LED Lighting Strip for $99 when purchased as a bundle (1 x SL3954, 1 x XC3802, 1 x ZT2400, 1 x RR2774, 1 x ZV1505, 1 x RE6070, 1 x RZ6627, 1 x HP9556, 1 x HM3172, & 1 x HM3173). Page 5: BONUS Gift: Spend over $30 on products advertised on page 5 and receives 1 x 4-in-1 Tape Measure (TH2510) per transaction. Page 6: Club Exclusive Offers: FREE 1 x Cat5E Cable (YN8308) with purchase of Balun Extender (AC1671). Buy both 9" LCD Monitor (QM3874) and Flush Mount Reversing Camera (QC3530) for $199. 15% OFF HDMI Leads & Adaptors applies to Jaycar 505C: AV Leads & Adaptors – HDMI Leads & Adaptors product category excluding WQ7496.



NEW LOCATION
Capalaba
96 Redlands Bay Rd, QLD 4157
PH: 07 3245 2014

For your nearest store & opening hours:

1800 022 888
www.jaycar.com.au

Over 100 stores &
130 resellers nationwide

jaycar
think. possible.

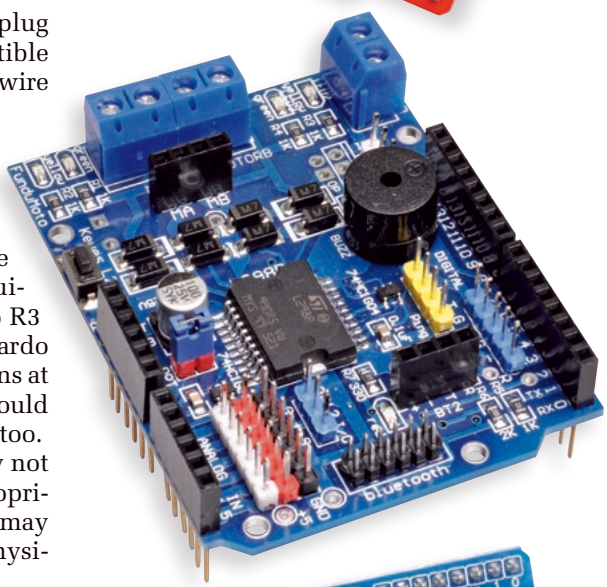
Head Office
320 Victoria Road,
Rydalmere NSW 2116
Ph: (02) 8832 3100
Fax: (02) 8832 3169

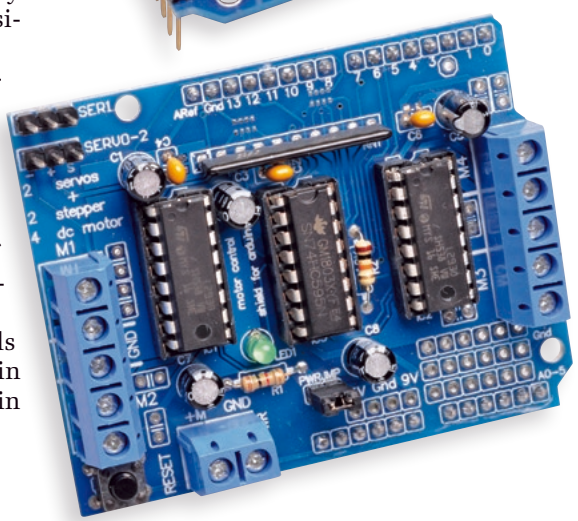
Online Orders
www.jaycar.com.au
techstore@jaycar.com.au

Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from catalogue sale 24.9.19 - 23.10.19.

ARDUINO MOTOR DRIVER SHIELDS

Are you building an autonomous robot or vehicle, or perhaps a CNC mill? You'll need motors and something to drive them. In this article, we take a look at three motor driving Arduino shields that could form the heart of your next 'mechatronics' project.





by Tim Blythman

In the February 2019 issue, we described how to use three different stepper motor driver modules (siliconchip.com.au/Article/11405). Stepper motors are great for precision control, such as is needed for a CNC machine or 3D printer, but they are slow and power-hungry, and do not suit every application.

Even in CNC machines, a conventional brushed DC motor may be used for tasks such as spinning the cutting tool or raising and lowering the platform.

A simple DC brushed motor (probably fitted with a gearbox) will turn faster and with much more power than a stepper motor, at a much lower cost. They're also pretty easy to control.

To control these types of motor from a microcontroller, a different kind of driver circuit and control module is needed. To drive a brushed DC or universal motor in either direction, we need a so-called H-bridge. All three Arduino shields described here use different integrated H-bridge driver ICs.

It's called an H-bridge because its logical configuration resembles the letter "H" in shape. You will see this resemblance if you take a look at Fig.1. This shows the four useful states of an H-bridge. In the three shields described here, the entire H-bridge function, including control and switching elements, is incorporated entirely within a single chip.

A shield is a module that can plug directly onto an Arduino-compatible main board, removing the need to wire it up pin-by-pin.

Of course, the shield format locks in a specific pin allocation which cannot be easily changed, but that is not usually a problem. For example, all these shields are designed to work with an Arduino Uno, but subsequent Arduino R3 format mainboards (eg, the Leonardo and Mega) place PWM capable pins at similar locations, meaning they should work with those host controllers too.

But note that other boards may not have been designed with the appropriate pin placements in mind and may not work, even if the shield will physically plug into their headers.

It's because of this Arduino-specific pinout that we won't delve into how these modules can be controlled with a Micromite. It's certainly possible, and we recommend that you look at our Arduino code samples if you're thinking of interfacing any of these with a Micromite.

Interestingly, one of the shields makes use of an L298 IC. This IC (in a different package) was also used in

one of the stepper motor drivers we reviewed in the February article on stepper motors mentioned above. We noted at the time that the module being described could also be used to drive a pair of brushed DC motors.

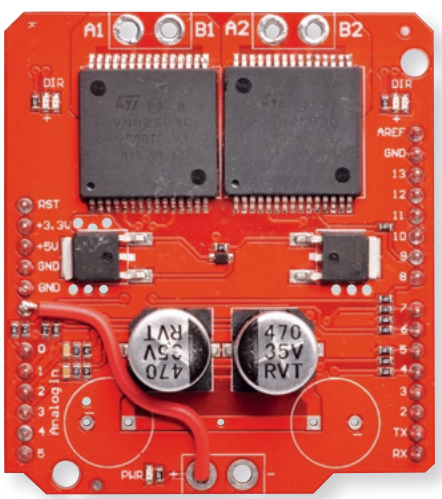
However, the reverse is unlikely to be true; we don't think any of these modules would make good stepper motor drivers.

But one great thing about all three of these shields is that they have outputs capable of driving two DC motors in either direction with varying speeds. One of the shields can control four motors.

It is handy to be able to control two or more motors as that allows skid-steer control (like a military tank or other tracked vehicle) to be implemented. While that has some disadvantages, it is elementary to implement in hardware as there are no complicated steering linkages or mechanisms. Skid-steer also provides the option to turn on the spot.

Shield 1: Monster Moto shield

The first shield is labelled as a Sparkfun "Monster Moto Shield". Sparkfun is a company based in the USA which has been designing and selling Arduino parts for many years. Many of these designs have been copied, including, we suspect, the Monster Moto Shield.



The Monster Moto shield is quite simple, although it has quite a few tiny SMD components. If necessary, the driver ICs could be heatsinked by the addition of self-adhesive PGA heatsinks such as Jaycar Cat HH8580. The red wire was added to allow the shield to be powered from the attached Arduino's DC jack for testing at modest power levels.

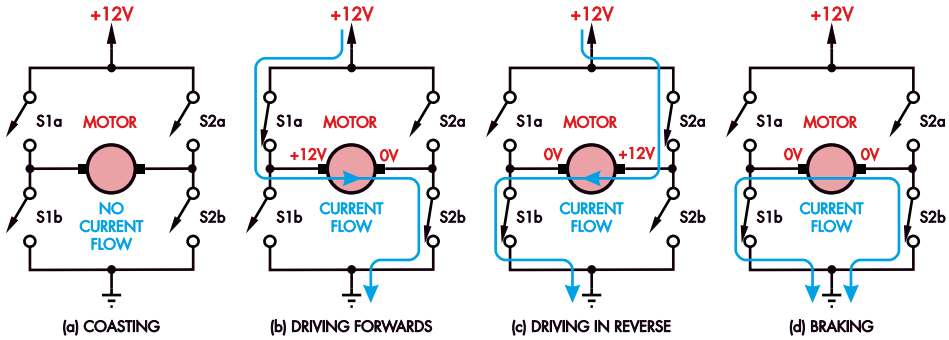


Fig.1: four of the five possible configurations of an H-bridge; the fifth is the same as (d) except that the braking current flows in the upper loop, which provides no real benefit. In each case, the voltage across the motor and the current flow path is shown, assuming a nominal 12V DC supply. In case (d), the current flow direction depends on the direction of motor rotation at the time of braking. The switches can be Mosfets, bipolar transistors, IGBTs or even relay contacts.

Unlike the other two shields in this article, the Monster Moto Shield was not supplied pre-fitted with headers. This can be handy, as you may wish to choose between stackable headers and male headers, although the height of the capacitors on this board would probably not leave enough clearance for another board to be fitted above.

We fitted our unit with male pin headers for our tests.

The two chips which provide the motor driver function take up around one-third of the board space between them. They are two ST Microelectronics VNH2SP30 ICs, which provide the interface between logic level signals and the motors.

Apart from these, there are two 35V 470µF bypass capacitors, two Mosfets and an assortment of tiny surface-mounted components. The full circuit diagram for this shield is shown in Fig.2.

The VNH2SP30 ICs

According to the data sheet of the VNH2SP30, this chip can handle up to 30A at 41V with PWM control at up to 20kHz. These are absolute maximums; in practice, they are difficult to achieve with this board, due to its lack of heatsinking.

The 41V limit is also a bit misleading, as the datasheet says that the maximum sustained operating voltage for the IC is 16V.

Two VNH2SP30 ICs are provided on the shield, and each IC implements a full H-bridge, meaning that two motors can be driven bi-directionally by the shield.

Operation is typical for this sort of IC. Two inputs (IN_A and IN_B) determine the direction of rotation, and a third input can be fed with a PWM signal that modulates the outputs, allowing for speed control.

When input IN_A is high and input IN_B is low, the motor rotates in one direction with a speed related to the PWM duty cycle. If IN_A is low and IN_B is high, the motor rotates in the other direction. If both inputs are high or both inputs are low, the motor is braked.

The chip provides current sensing and fault detection, and these signals are fed to pins on the shield for processing by an attached Arduino board.

The EN pin functions as an enable input, and is pulled up by a resistor on the shield during normal operation. An internal fault condition will cause this pin to be pulled to ground, disabling the device and alerting a connected microcontroller via pin A0 or A1. These pins can also be driven low to achieve the same shutdown effect for each driver IC.

There is also a CS pin (current sense, not chip select) which sources a current proportional to the motor current. A resistor on the shield converts this into an analog voltage, which is smoothed by an RC network before being connected to an analog pin on the shield (A2 or A3). This allows the motor currents to be measured by the attached Arduino's analog-to-digital converter (ADC) peripheral.

Other important components

Apart from the main driver ICs, a pair of 470µF 35V capacitors bypass the motor supply voltage. Two Mosfets, along with a resistor and zener

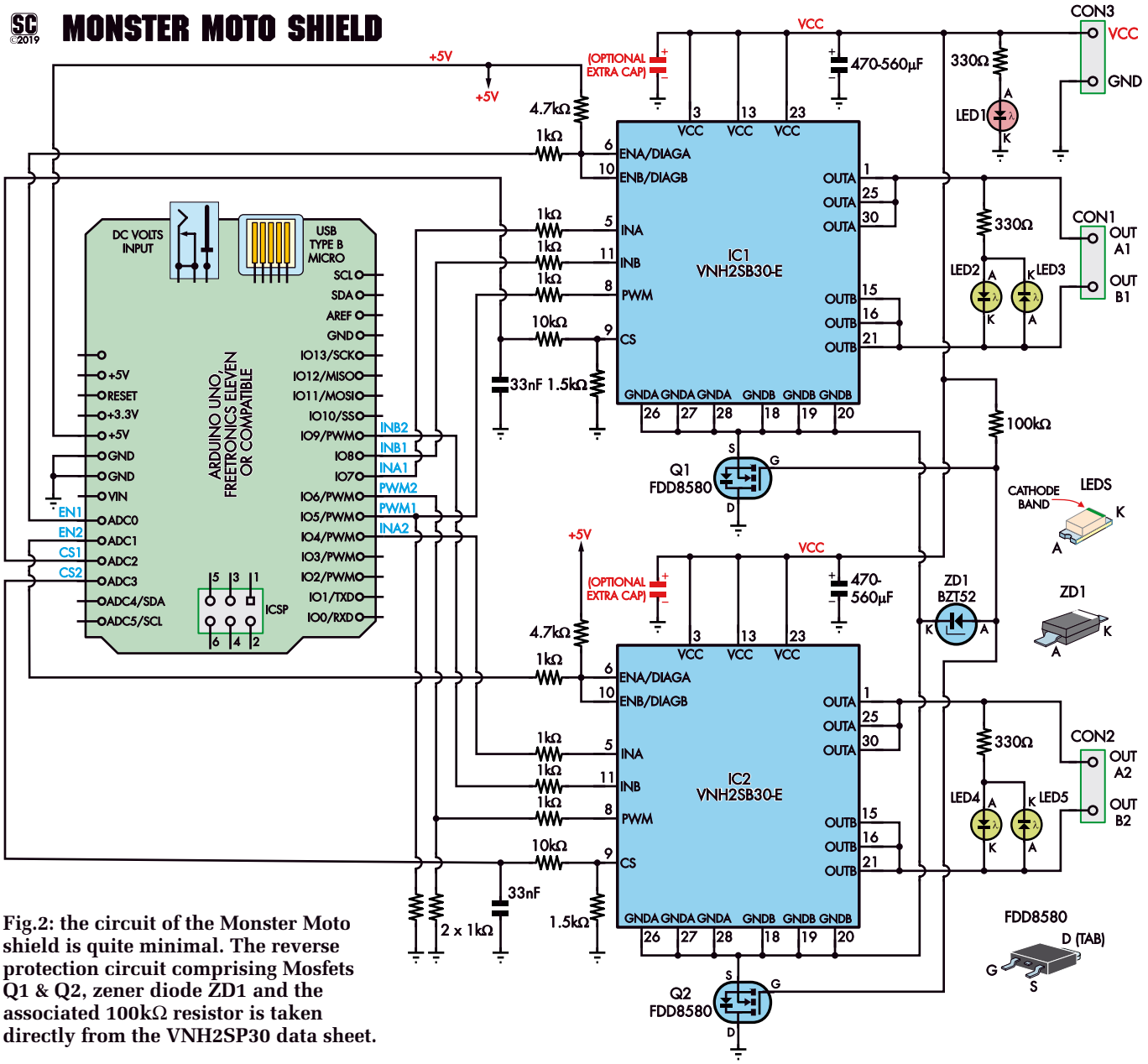


Fig.2: the circuit of the Monster Moto shield is quite minimal. The reverse protection circuit comprising Mosfets Q1 & Q2, zener diode ZD1 and the associated 100kΩ resistor is taken directly from the VNH2SP30 data sheet.

diode, provide reverse polarity protection to the driver ICs.

The ICs are only powered when a voltage of the correct polarity (and above the Mosfet's threshold voltage) is applied.

There are five LEDs to provide a power-on indication for the shield as well as power and direction indication for the two bridge outputs, and thus any connected motors.

Series resistors between the Arduino pins and the control inputs of IC1 & IC2 protect those ICs should the Arduino try to send control signals when the motor power supply is absent, and pull-downs on the PWM pins mean that the motors will not turn if the pins are not being driven (eg, while the Arduino is being programmed or reset).

Using it

Table 1 shows the I/O pin connections between this shield and an attached Arduino. They are mostly well-chosen, with the PWM control pins being connected to PWM-capable outputs on the Arduino. The analog pins are carefully chosen to avoid pins A4 and A5, which are multiplexed with the hardware I^2C function on Uno (ATmega328 chip based) boards.

It's apparently quite an old design as it lacks the header locations for the dedicated I^2C pins near AREF, and thus appears to predate the Uno R3. This should not cause any problems unless you need to stack multiple shields. The easy fix is to attach this shield to the top of the stack.

The use of digital pin 3 may be problematic if this board is to be used with a Leonardo, as the hardware I^2C function is found on pins 2 and 3 on that controller. Other 5V boards (such as the Mega) should be fine, as they do not have these sort of conflicts.

The VNH2SP30 data sheet indicates a 3.25V minimum input level for the logic level pins, meaning that operation may be borderline on 3.3V microcontrollers like the Micromite.

Power

Power for the motors is brought in through a pair of large solder pads at

one end of the board. The GND connection is common with the Arduino's GND, but there is no connection to the V_{IN} connection on the Arduino shield. This means that you have to apply external power to test the board. A wire could be soldered to the board if the Arduino's power needs to be fed from the shield.

We soldered a wire from the Arduino's V_{IN} pin (on the shield) to the shield's positive supply to allow us to test with a 12V plug pack feeding the Arduino's DC jack. This obviously only allows modest current levels, but we were able to test our demonstration sketch.

The other two shields we'll describe later have a jumper to allow this connection to be made or broken without soldering.

Also, the input power connection sits directly above the ICSP header, so care must be taken that the power connections do not bridge to this header when the shield is plugged in.

Similarly, the motor outputs come out near the USB socket end of the board. The connections for motor two come close to the USB socket. They don't appear to touch it, but attached wires may do so. We applied some electrical tape to the top of the USB socket on our Arduino board to avoid mishaps.

Sample code

Our sample code (MonsterMoto_Demo.ino) allows direct control of each motor's speed using commands in the Serial Monitor. Enter a letter ("A" or "B", for the motor output), followed by a number between -255 and 255 for the motor speed. Negative values give rotation in the opposite direction to positive values, and higher values give faster rotation.

The code also prints the raw analog values from the CS (current sense) pins to the Console every 200ms.

The current sensing on the CS pin has a nominal output ratio of 11,370, meaning that a current of 11.37A or 11,370mA from the driver would result in a 1mA current from the CS pin. This passes through a 1.5kΩ resistor to convert it into a voltage suitable for the Arduino's ADC.

The ADC can read a maximum of 5V, which corresponds to 3.33mA through the sense resistor or a nominal 37.9A (3.33mA × 11,370) at the driver output. Given that there are 1024 steps in the ADC output, each step corresponds to around 37mA of motor current.

Shield 2: FunduMoto shield

The FunduMoto is a bit of a contrast to the basic-but-powerful Monster Moto shield. The top of the shield is more tightly packed with components. Not surprisingly, it boasts a more diverse range of features and options. Its circuit diagram is shown in Fig.3.

CON1 and CON2 provide two different options for wiring up the motors, while CON3 is for the motor power supply and JP1 (labelled "OPT" on the board) allows the Arduino's V_{IN} rail to power the motors.

The shield also sports a buzzer and several extra headers. It is well-suited to form the basis of a small robot project, as these headers allow other modules and motors to be easily and directly connected to the shield.

The buzzer is quite loud and shrill. It's almost too alarming to be used for anything but a genuine emergency, as it's unbearable to have it running for too long.

CON4 and CON5 can be used to connect two servo motors, eg, for steering control. These are controlled by pulses from digital outputs D9 and D2 respectively, and the pin-outs suit many standard servos. CON6 and CON7 are designed to allow two different types of Bluetooth modules to be connected, for remote control and feedback. CON8 allows just about any RGB LED to be driven from the Arduino.

CON9, labelled "ping", suits certain ultrasonic distance sensor modules (similar to those we reviewed in December 2016; see siliconchip.com.au/Article/10470). Such a sensor could be used by a robot to detect if it is about to run into something and act to avoid a collision.

If the ultrasonic distance sensor could be mounted to the rotating head of a servo motor, then the robot can detect not only what is straight in front of it, but scan its surroundings by rotating the servo motor via CON4 or CON5.

The L298P IC

The driver IC on this shield is an L298P, which is the same one used in our stepper motor article, mentioned earlier, but in a different package. The L298P includes two full-bridge motor drivers, so can drive two motors bi-directionally.

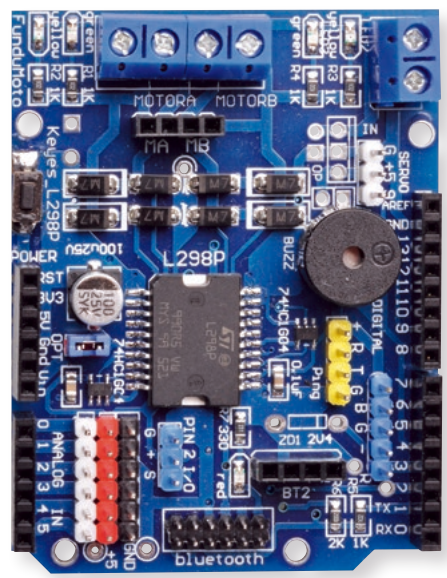
Its maximum supply voltage is 46V, and it can source or sink up to 2A continuously on each channel. The maximum PWM frequency is 40kHz.

The bypass capacitor on the shield is only rated to 25V, so this limits the maximum supply voltage you can apply. Note that most Arduino boards can only handle up to 20V on their V_{IN} pins (some only 15V, depending on the voltage regulator fitted), so there are multiple factors to be considered when using this shield with motor supply voltages above 15V.

The L298 IC has provision for a shunt resistor to be used to measure motor current, but this has not been taken on the shield, meaning motor current cannot be easily measured. To add this would involve lifting two of the IC's pins (pins 2 and 19) and fitting a shunt resistor between these pins and ground.

Some signal conditioning components (eg, an RC filter or similar) would also be needed to average the current throughout a PWM cycle, if you want current feedback.

Free-wheeling diodes are recommended for the outputs of the L298, to absorb back-EMF spikes and also energy generated by the motor as it runs down; these are fitted, although they are M7 silicon diodes (D1-D8; equivalent to 1N4007) instead of the recommended fast-recovery schottky



The FunduMoto shield looks complicated, but much of the space is taken by headers for sensors and the motors. The L298P has a large body which could accommodate a heatsink. The 2x6 2mm pitch header is for an obscure automotive Bluetooth module.

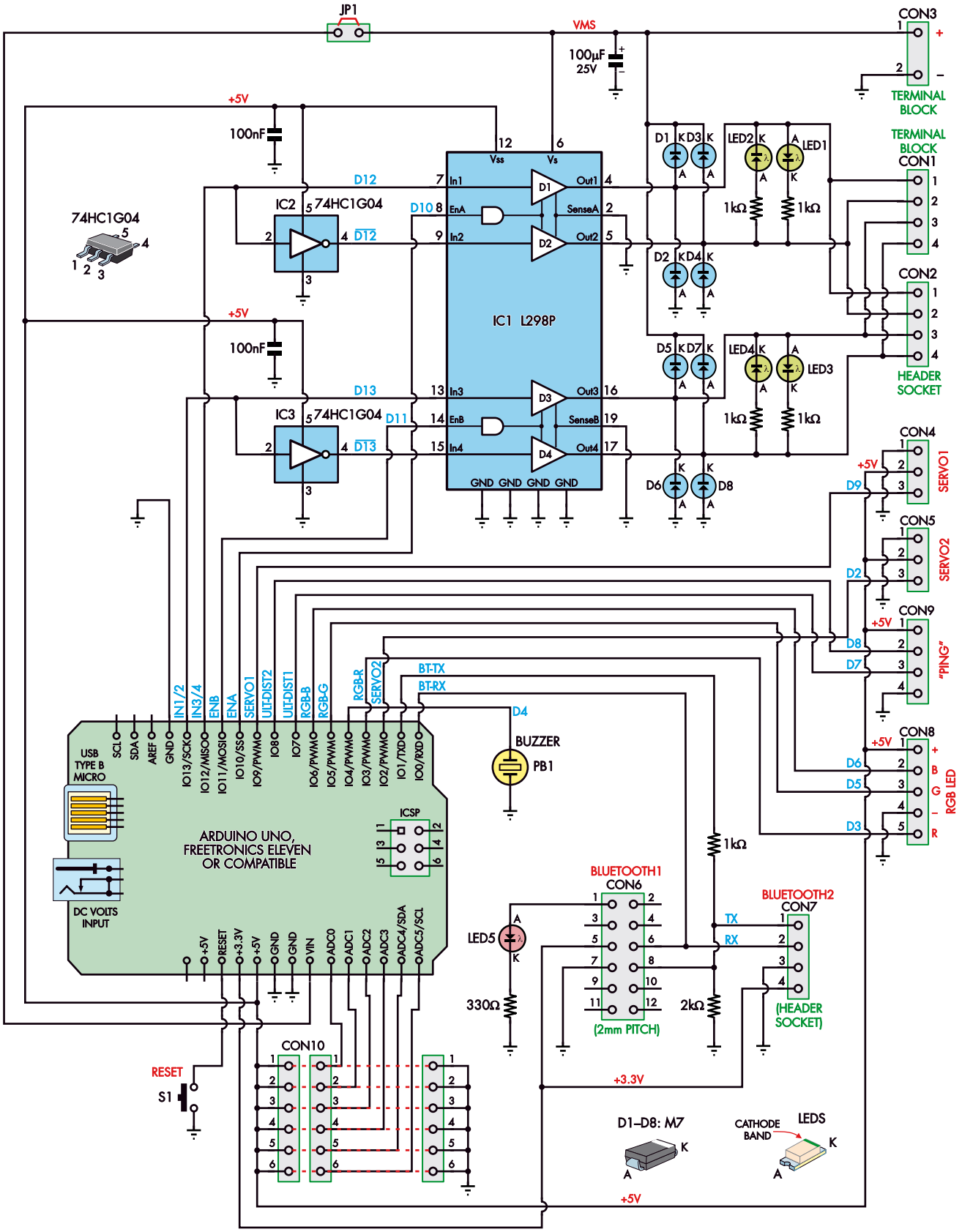


Fig.3: the FunduMoto shield circuit shown here includes two motor driver ICs, numerous headers plus eight free-wheeling diodes and a tactile pushbutton switch (S1) which can be used reset the attached Arduino processor board.

diodes, which means they will run hotter.

This shield also appears to predate the Arduino Uno R3 layout, so any R3 shields should be stacked below this shield to ensure that necessary connections are made.

Other components

The L298 has two inputs per motor channel for direction control. On this shield, complementary drive signals are generated by a pair of tiny 74HC1G04 single inverter ICs (IC2 & IC3). While this reduces the number of I/O pins needed to control the motors, it removes the option of driving both inputs low to force dynamic braking.

This is a factor in making this shield less suitable for driving stepper motors, as it is harder to generate some intermediate step positions without braking.

CON10 allows a three-wire analog sensor (with GND, 5V & OUT connections) to plug straight in. You can also use this header to tap off 5V power, ground or make a connection to one of the analog pins. The shield also has an onboard reset button, in case you can't get to the one on the Arduino.

Using it

The V_{IN} pin supplies power to the Arduino board's 5V voltage regulator, similar to power being applied to its DC jack. In spite of this, it's not a good idea to feed power in through the DC jack to the attached shield, as there is usually a small reverse polarity protection diode between the DC jack and V_{IN} pin on the Arduino board. The current drawn by the motors could burn this diode out.

The better alternative is to feed power directly into the shield, either via the V_{IN} and GND pins or the screw terminals. The attached Arduino board is then powered via its connection to the V_{IN} pin. Of course, there is no reverse polarity protection in this case.

The Arduino pin connections are shown in Table 2. Apart from the direction, PWM and buzzer, none of the functions shown in Table 2 have any effect unless something is actually connected to the shield, so the pins remain available if needed for other roles, for example, if a second shield is attached.

We have written a sample Arduino sketch to test some of the features; it operates similarly to the Monster Moto shield sample sketch, except there is no display of motor current. It is named "FunduMoto_Shield_Demo.ino".

While LED1-LED4, near the motor screw terminals, appear to be a handy aid to show what the motor is doing, they unfortunately both tend to light up any time a motor is connected and powered, presumably due to back-EMF during the PWM off-cycle.

Shield 3: L293D-based motor and servo shield

This shield is stocked by both Altronics (Cat Z6208A) and Jaycar (Cat XC4472), and features two L293D dual motor driver ICs as well as a 74HC595 serial-to-parallel shift register. On our version of the board, all three ICs were fitted via sockets. Its circuit is shown in Fig.4.

It is a clone of a board originally designed by the Adafruit company, and it makes good use of the original Uno's six PWM outputs. It is a fairly old design, and as such also lacks the R3 header connections (this is becoming a theme...). The supplied headers are not stackable, but being such a bulky shield, it makes sense for it to be the top-most board in a multi-shield stack anyway.

The big upside of this board is that it is capable of driving four bi-directional DC brushed motors. It also features two servo headers, and all six analog-capable pins are brought out to headers too (although these headers were not fitted on the board we tested).

The L293D IC

The L293D motor driver IC is very similar in function and layout to the L298, although with more modest current and voltage capabilities. It has the benefit of being available in a convenient 16-pin DIP format. Both Altronics and Jaycar stock the bare L293D IC as well as the shield, so you have the option of developing your own hardware or even replacing a blown chip if that were to happen (never!).

The IC is rated at 36V supply voltage and up to 600mA continuous current per channel. This is sufficient for many of the smaller hobby or gear motors that are around. The contact between the IC and its socket may introduce extra resistance, so these ratings may not be achievable with the socketed ICs.

Our version of the board is populated with 16V electrolytic capacitors, so would not be able to withstand any voltages higher than this (they could be upgraded).

The IC itself also incorporates shunt diodes, so direct connection to inductive loads is straightforward. It does not provide any provision for detecting current.

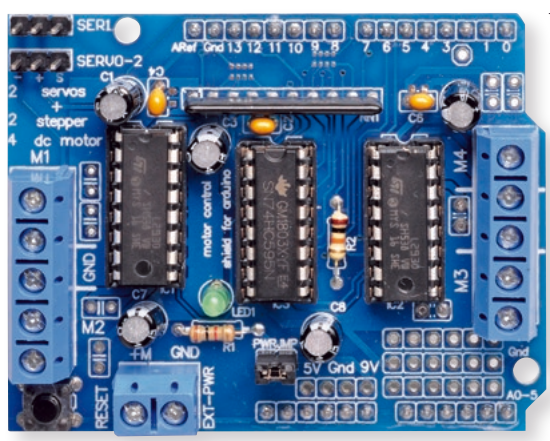
The data sheet does not specify a maximum PWM frequency, although the consensus within the Arduino community is that 5kHz is about the maximum usable. The PWM signal is fed into an enable (EN) pin, which is shared by the two outputs that feed a single motor.

By default, the AVR-based Arduino boards like the Uno have a default PWM frequency of either 490Hz or 980Hz (depending on the pin), so will be fine driving this shield if you don't change that.

The 74HC595 chip

The presence of a 74HC595 shift register (IC3) means that this shield does not require eight separate digital outputs to drive the motor driver ICs. That's fortunate, as it would otherwise use up a great many of the available I/O pins on a standard Arduino.

Instead, the motor state is set indirectly via the shift register, although the PWM outputs come directly from the attached Arduino board, since the shift register would not be



The L293D shield uses all through-hole parts and socketed ICs, making replacement of damaged parts easy.

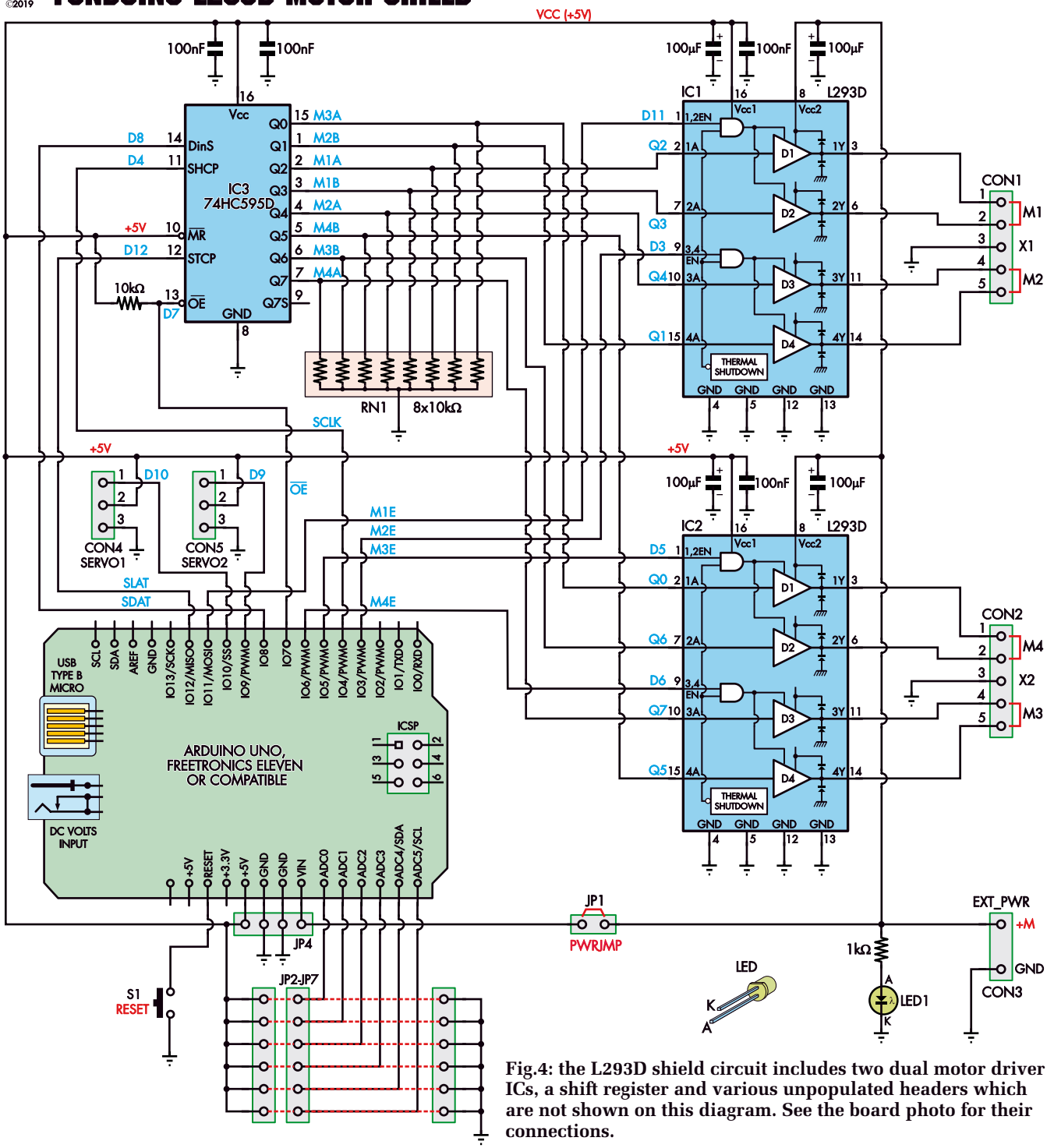


Fig.4: the L293D shield circuit includes two dual motor driver ICs, a shift register and various unpopulated headers which are not shown on this diagram. See the board photo for their connections.

able to update quickly enough. Table 3 shows the connections for this shield.

The $\overline{OE}$ (output tri-state) pin of the shift register is also connected to an Arduino pin, meaning the entire unit and all its motor outputs can be effectively switched off by that one pin.

There are a handful of other components on the shield, including an assortment of capacitors and several unpopulated headers. Two three-way headers are fitted to one corner for servo motor connections. A resistor network provides pull-downs on the outputs from the shift register so that a safe state is present during initialisation.

Screw terminals are provided for feeding power in (CON3) as well as the motor connections.

The motor connections are via two five-way screw terminals (CON1 & CON2), one at each end of the board, with the centre terminal of each connected to ground.

This allows this shield to drive up to eight devices (including lamps) if polarity reversal is not needed, ie, by connecting them between one motor output and ground, instead of between a pair of outputs.

Wagner
ELECTRONICS SUPER STORE
OVER 40 THOUSAND PRODUCTS
ONLINE 1500+ PAGE CATALOGUE
AUSTRALIA WIDE SHIPPING

AUDIO/VISUAL ACCESSORIES
SPEAKERS / PRO AUDIO
ELECTRONIC COMPONENTS
DATA & ELECTRICAL
TOOLS & TEST EQUIPMENT
BATTERIES & MORE!
BUY ONLINE AT
WAGNERONLINE.COM.AU
VISIT OUR SYDNEY STORE
84-90 PARRAMATTA ROAD,
SUMMER HILL, NSW 2130
02 9798 9233

Like the FunduMoto shield, a jumper (JP1, marked PWRJMP on this shield) is provided to make or break the connection between the motor power supply and the Arduino's V_{IN} pin.

Using it

Table 3 shows the L293D Motor Shield's connections.

We found that some of the pins on the shield's underside protruded quite badly, so we trimmed the pins of the screw terminal blocks and applied insulation tape to the USB connector of our Uno before connecting it. The pins were so long that the shield would not sit flat on the Arduino before trimming.

While it may seem excessive for the L293D motor shield to be able to drive four motors, we think it would work well with some of the four-wheeled robot chassis that exist, like Jaycar Cat KR3162 or Altronics Cat K1092.

The motors need not be driven independently in software, and the plentiful screw terminals make it easier to terminate the motor wiring separately.

Our test sketch for this shield is called "L293D_demo.ino". It operates similarly to the other two sketches, except that there are now four motors available to be controlled, and they are designated A through D, corresponding to M1 through M4 as marked on the headers on the shield.

Summary

We did not try to push any of these shields to their limits. Except for the Monster Moto Shield, the voltage limits of the ICs are overruled by the capacitors that have been installed. Our testing was also done at quite low current levels, and you may find that some form of heatsinking or ventilation may be needed at higher currents.

The Monster Motor shield will drive bigger motors than the other two, with the FunduMoto shield being between the other two in terms of motor size capability.

It's worth noting that due to the inductive nature of DC motors, voltages higher than the supply might be present when the motors are switched off, such as at the end of a PWM cycle. The capacitors will need to be able to handle this too.

For the basis of a simple robot car project, the FunduMoto shield would work well. The various headers allow many sensors and other devices to be connected directly to the shield, simplifying the wiring for such a project.

If more motors need to be driven, then clearly the L293D shield is the best choice, with its ability to drive four motors. Unfortunately, none of the shields offer any option for pin swapping, so there is no real option to stack multiple boards to provide more outputs than this. SC

Table 1: Monster Moto Shield Connections

Function	Motor 1	Motor 2
IN_A	7	4
IN_B	8	9
PWM	5	6
EN	A0	A1
CS	A2	A3

Table 2: FunduMoto Shield Connections

Function	Pin
Direction (Motor 1 & 2)	12 & 13
PWM (Motor 1 & 2)	10 & 11
Buzzer	4
Servo 1	9
Servo 2	2
Analog	A0-A5
Ping Trigger	7
Ping Receive	8
RGB	3, 5 & 6
Bluetooth	0 & 1 (TX & RX)

Table 3: L293D Shield Connections

Function	Pin
74HC595 Data	8
74HC595 Clock	4
74HC595 Latch	12
74HC595 Enable	7
PWM Motor 1-4	11, 3, 5 & 6
Servo 1	10
Servo 2	9

CABLE ASSEMBLY and BOX BUILD ASSEMBLY

- Metal Work
- Label and Wire Marker
- CNC Engraving and Machining
- Functional Test and Logistic Service

High mix low volume and quick turnaround

Electrical box assembly

Fully automatic cut, strip and crimp machines

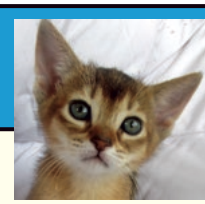
AT AMPEC we specialise in manufacturing of custom design cable assemblies as well as turnkey electronic and electric product assemblies.

+61 2 8741 5000
sales@ampec.com.au | www.ampec.com.au

ampec TECHNOLOGIES

SERVICEMAN'S LOG

A shockingly cute new companion



Maggie Thompson

Training pets, especially of the feline variety, can be difficult. However, as is common nowadays, there are likely close to a myriad of ways to help. One method is via a "pet training mat", which emits a buzz and 'small' electric shock, with all the safety you would typically expect from cheap electronics sold online.

Items Covered This Month

- The cat in the mat
- Hot water system repair
- Yamaha CR-1020 restoration
- Mitsubishi ABS pump repair

Dave Thompson runs PC Anytime in Christchurch, NZ.

Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

We recently got a new cat (or, perhaps more accurately, the cat got some staff to look after it). This feline is as cute as a button and therefore impossible to discipline properly.

While many cat owners allow their pets to walk all over the kitchen benches and scratch the furniture, we don't. Footprints on work surfaces and shredded mattresses and armchairs may well be part of the 'joy' of cat ownership, but we have always deterred our furry housemates from this behaviour.

We've used several training methods over the years, the most technological of which was a slightly modified version of the SILICON CHIP "Nick-Off" Bad Cat Deterrent (October 2012; siliconchip.com.au/Article/502). We found this worked for our cats at the time.

However, they eventually got wise to it and ended up blatantly ignoring it. They would jump onto the cooktop and bench, to either drink out of the sink (their expensive cascading water fountain is obviously not good enough!), or scavenge their share of the roast we'd just eaten for dinner.

While we'd managed to train all our cats, past and present, not to do this with a combination of water squirting bottles, sticky tapes, deterrent sprays and electronics, the new addition did and went where it liked. When the older cat saw this, his old habits started creeping back in.

I'd long-since repurposed the Nick-Off for another project. But while I was browsing for parts to build another one on AliExpress, I spotted a possible solution: electronic pet training mats.

These seem to be a hot product these days, both on local and international shopping sites. I was aware of such devices, but in the past, I was put off them because the one I saw was not user-friendly and a bit too aggressive in operation.

Admittedly, it was designed for a medium-sized dog, but even on the 'low' setting it still delivered what I considered a nasty shock, out of proportion to the 'crime' of the dog sitting on the owner's favourite chair. The mat or sensor part of it was also rigid, prickly to handle due to embedded wires tracks and hard to clean.

I've never been a fan of giving electric shocks on purpose, having suffered a few 'good ones' over the years.

Because of this, I have some empathy and a natural aversion to deliberately shocking anyone (or anything). I especially despise those 'joke' shock-pens and cigarette lighters that were all the rage at one point; I don't think lighting someone up deliberately is funny at all. I can't recall seeing anyone blitzed by one of those things rolling on the floor laughing. Mostly they just look annoyed…

Anyway, I figured there must be some better training mat options available these days, so I went online to check. The modern versions are inexpensive and sized for different pets, with adjustable shock levels and more flexible, easier-to-manage sensor mats. I found similar products for sale at local pet shops, but at significantly higher prices.

The pitfalls of buying online

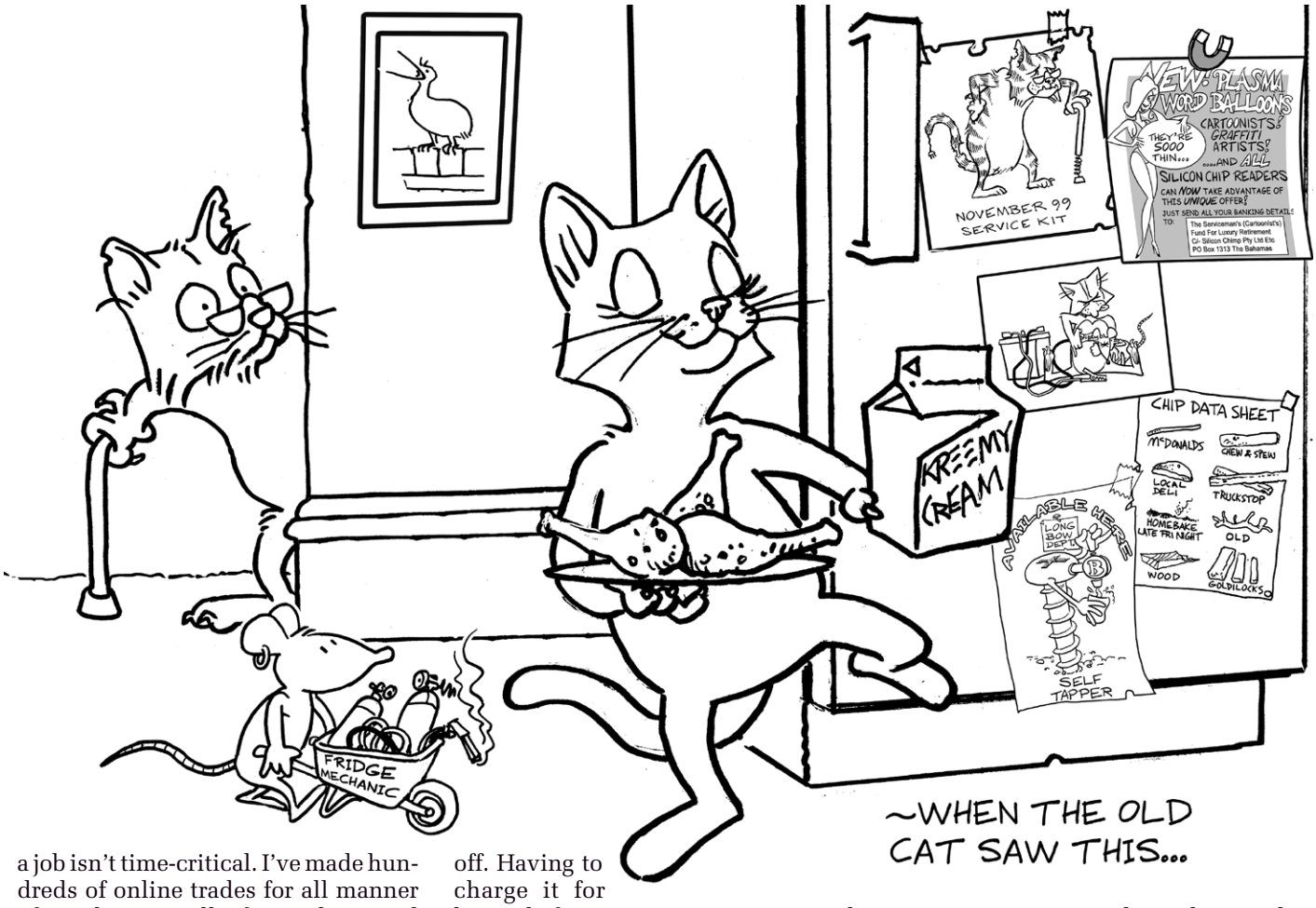
I'm not a cheapskate, but I do object to being gouged by local sellers. The typical reason thrown about for exorbitant mark-up on just about everything imported into New Zealand is "shipping costs". That excuse may have washed fifty years ago, when nobody really knew the true cost of goods, but these days everyone knows that it doesn't justify the prices many local sellers try to charge.

So it is no wonder that buying from overseas vendors is increasingly popular!

But there are challenges to ordering online. So many products look very different when they arrive from the often-doctored pictures on vendors' sites.

The benefits of buying locally are obvious; stores typically have what you want, have regular sizing and naming conventions throughout product ranges, and you can always take something back and (typically) get a refund or a replacement if necessary. Sending anything, especially something of relatively low value, back to an overseas vendor is usually neither practical nor financially feasible.

In practice, I shop locally for some items and use overseas vendors only when this makes financial sense, or if



a job isn't time-critical. I've made hundreds of online trades for all manner of goods, generally from China and the USA, and while I have had mostly positive experiences, there have been some hiccups.

I purchased several cameras from China only to be disappointed. One, a GoPro-style action camera, claimed to be able to record video at 4K resolution (3840x2160 pixels) and 60 frames per second (fps). This is ostensibly backed up by the words 4K emblazoned across the front of the case.

But my attempts to record anything with it higher than 720p (1280 x 720 pixels) and 25fps resulted in unusable video. It'll record at 4K, but only at around 1fps. If a local retailer advertised and sold such a product, their shop would be razed by a pitchfork-and-torch-wielding mob. But online vendors will happily hawk this and similar products with the knowledge that there's little we can or will do about it.

Another much more expensive action camera I bought online last year (I was learning!) works much better, but still had problems. It will record at 4K and 60fps and has remote control via app, Bluetooth and WiFi, among others. But the battery went flat overnight, even when the camera was switched off. Having to charge it for hours before every use was a royal pain in the lens cap.

When I looked into this, other buyers had the same problem, and a firmware update was apparently the answer. I eventually found and downloaded the firmware. The update resolved that issue, but it was a lot of extra work when it really should have worked properly in the first place.

As always, it comes down to "caveat emptor"– buyer beware – particularly with more significant purchases.

Bringing the felines back in line

Anyway, because of the relatively low price of these training mats, and with a lack of other ideas, we ended up buying two small pet training mats from AliExpress.

When they arrived a few weeks later, the hazards of online shopping were once again apparent. While the mats were pretty much as advertised, their construction is what one would expect from such a cheap product. Only one of them arrived in working condition.

The mats are powered by three AA cells; I hope they do not chew through them too quickly, as that could get expensive. If push comes to shove, I'll modify them to run on one of the dozens of spare plugpack power supplies I have taking up drawer space in my workshop. But before fretting about that too much, I needed to fix the broken one.

The mat's controller is a sausage-shaped plastic housing with a flattened bottom that sits along one short edge of the rectangular mat. It has a three-cell battery holder with a removable lid, and a single button on the top to switch the power on and off when held down. Short presses cycle through the

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

three shock settings: low, medium and mad scientist. This is indicated by three small LEDs.

There is also a built-in piezo buzzer that chirps when the button is pressed and quickly sounds multiple times if the sensor pad detects anything. The pad resembles a large, flexible-plastic thin-film PCB with closely-interlocking printed silver tracks.

Briefly bridging the tracks results in a warning alarm, but no shock; if contact is maintained for more than a few seconds, a shock is delivered through the tracks at the level selected. I'm too chicken to put my hand on it, but I did bridge the tracks with a short length of hook-up wire and there was a frankly unnerving amount of crackling and popping at the connections, even on the lowest setting.

There also appeared to be an undocumented feature; a vibration sensor in the controller triggers the warning beeps (but not the shock) when movement is detected. Even lightly bumping the bench sets it off.

Fixing the obvious fault

Disassembly of the faulty mat was easy. Thankfully, there were no dumb anti-tamper fasteners; just eight small, cross-head PK screws to remove from the bottom of the controller. The two moulded halves then came apart. The electronics look surprisingly comprehensive and well-made, with a host of SMDs and a couple of those blob-style COB (chip-on-board) ICs on the board.

Cloth insulating tape covered some of the components on the 'hot' end of the board, and initially, I left that in place. The circuitry was more complex than I expected to find, and with PCB component soldering looking good, my expectations of an easy fix might have been misplaced.

I found that the two HV output connections between the mat and the PCB were just stripped-bare hook-up wires, flattened out at the ends and clamped onto 'terminals' on the mat between the two halves of the case. A screw through the centre of each terminal ensured a solid connection.

I don't consider this to be a particularly elegant solution, but it's probably effective as long as the contacts are not disturbed too many times by repeated disassembly.

I wasn't sure how rugged the sensor tracks were. They appear to be made from conductive silver paint, screen-printed onto the clear plastic mat; scratching through a track at any point would break its continuity. While one of the PCB wire-to-pad connections might have been where things had failed, my gut feeling was that while basic, the contacts should be OK.

To take the PCB out, I had to remove a couple of small hold-down screws.

I also needed to release the positive battery terminal, which clips

into a moulding in the top half of the controller and has a metal tongue that extends down into the PCB cavity below, where it attaches to a solder pad on the 'input' end of the board.

After removing the PCB screws, I turned the unit over to see how that positive battery terminal should be removed, and the PCB fell out onto the workbench. I was reasonably sure the battery terminal should be soldered in, but a look under the magnifier revealed no solder on it at all. There was a corresponding blob of solder on the PCB though, with the shape of the tongue embedded in it.

It looked like it had been pushed into hot solder but had never been physically connected.

Thinking that it might be designed as a push-fit, for ease of assembly, I opened the other working mat to check. That mat's positive terminal was properly soldered in. I sat the PCB back in the dead one, cleaned the blobbed solder from the pad and tinned and re-soldered the tongue. A quick (and very careful!) check with batteries fitted showed this resolved the problem.

Reassembly was just as easy, though I took care around those fragile-looking contacts. How the mat passed QA checks (if any) is anyone's guess, but it's a good example of why buying online can be problematic. Someone who isn't afflicted with the Serviceman's Curse would have probably just binned the mat and taken the hit.

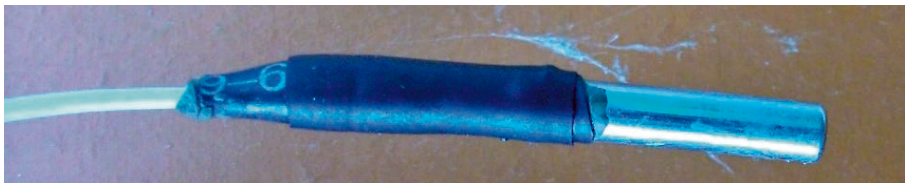
You'll be pleased to know the cats have come to no harm but very quickly learned not to walk on the bench. They now run off in every direction at the mere sound of those warning beeps!

Hot water system repair

A. K., of Armidale, NSW, had a solar hot water system installed in 2010. It worked well for years but recently went on the fritz and he had to fix it...

Periodically, I check the various temperature readings on the Solastat controller, more out of interest than any other reason. One sweltering day last summer, I noticed that the solar hot water controller was displaying the fault code "SSd" instead of the roof sensor temperature.

I checked the manual and "SSd" stands for "Smart Shut Down", where the system idles in case of a shorted or open sensor or cable wire. This fault can also be displayed when the temperature sensor is outside the specified temperature range of -40°C to +150°C.



The Solastat temperature sensor, shown above, was repaired by replacing a single NTC thermistor within it.

Upon further inspection, I found the roof sensor or cable was open circuit. Luckily for me, it was late afternoon so the corrugated iron roof had time to cool down from its peak temperature on that 33°C day.

I went up onto the roof to remove the sensor from its housing and noticed that very little sealing compound had been used. I decided to cut the sensor from the cable, leaving 10mm exiting the sensor. I probed these wire stubs with my multimeter and found that the sensor was open circuit.

The temperature sensor was potted in a small steel case. I picked away at the filling until I reached the sensor, a small beaded glass device with no visible markings. The user's manual didn't give any information as to its type.

I went onto the web and fortunately, Senztek (makers of Solastat controllers) have various manuals available for download from the website. I found an installation guide with a table of NTC sensor resistance readings at various temperatures. It specified a value of 10kΩ at 25°C.

Further web searches revealed an Australian site selling replacement 10m cable with roof sensor to suit Solatstat controllers, including free thermal paste and joiners. Tempting!

But fortunately, I already had some 10kΩ NTC thermistors which followed the temperature curve of the original sensor quite closely. The next day, I removed all the filling from the old sensor housing and replaced it with my new NTC thermistor. I used high-temperature epoxy putty to hold it in place and then re-soldered the sensor to the controller cable, adding two layers of heatshrink tubing for weatherproofing.

Where the sensor cable exited the corrugated iron roof was utterly devoid of any sealant and as it was another hot day, I decided to fix that later, in the cool of the evening. So I dropped down to my local electrical distributor and purchased a cable gland.

Back on the roof that evening, I Installed the cable gland in the roof, through which the sensor cable now ran. I smothered the sensor's metal case with silicone-based thermal paste and then slid the refurbished sensor unit into place. Finally, I used some neutral cure silicone sealant to secure the unit into the solar heater housing and prevent moisture ingress.

It has been nine months now since the repair and my new sensor has not missed a beat. The replacement NTC thermistor sensor I used cost me $3 while a replacement cable with sensor would have cost $65 and that's not including labour. I figure it was a job well done.

Yamaha CR-1020 receiver repair/ restoration

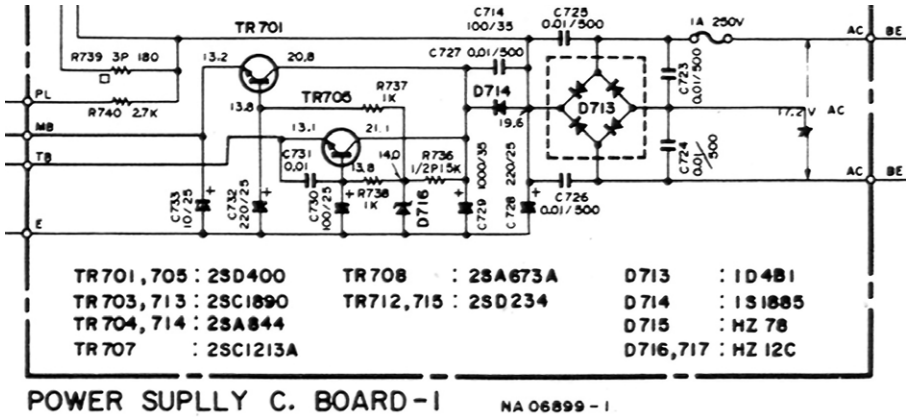
R. A., of Melbourne, Vic, decided to restore a retro amplifier to its former glory by fixing a few small faults which had developed over its many years of use. This is how he did it…

The Yamaha CR-1020 is a chunky receiver from the late 70s. It's powerful for its day at 80W per channel with 0.05% THD, both channels driven. It incorporates an excellent FM tuner. It originally cost $895, at a time when a base Holden HZ sedan started at $2150.

I snapped up this mint-condition receiver in 2014 for $400. It has given good service ever since. These now sell in the USA for well over $1,000, which prompted me to get to work fixing mine.

It had a few minor niggles: none of the lamps behind the fascia worked and the back panel switch that couples the preamp/tuner to the power amplifiers was scratchy. Working the switch a few times helped, but I prefer a permanent cure. Its timber case was also damaged in transit, on a lower front corner.

Opening it up, I found all five fascia lamps open-circuit. These "grain of wheat" lamps are nominally 12V/60mA. Four are located behind the three meters, connected in series/



parallel and powered from a 19.23V DC rail. The fifth is mounted on the tuning dial pointer and runs from a 9.68V supply.

The reduced rail voltages were intended to prolong the life of the lamps. The subtle glow also imparts an air of sophistication to the unit.

Googling revealed that it is common for these lamps to all fail, and that plenty of replacements are available, both LEDs and incandescent.

Oddly, all four lamps in a series-parallel circuit can fail; if one goes open-circuit, you would expect its parallel lamp to then fail, disconnecting the other two from the supply. But somehow, this does not happen.

I ordered some replacement incandescent lamps and then checked the supply voltages. The 19.23V rail (shown as 19.6V elsewhere in the circuit diagram), which also drives the speaker protection relay, measured just 13.5V.

I suspected a dud filter capacitor. My DSO showed significant ripple on this rail. Clipping two 100µF caps across it drove the reading up to 17.5V (with a low mains voltage of 227V), while a 2200µF cap increased it to 19.2V. So I was pretty sure that the original filter capacitor had failed.

While doing this testing, I also noticed that the speaker relay was pulling in with a very soft click, but with the larger capacitor added, the click was restored to its normal, strong sound.

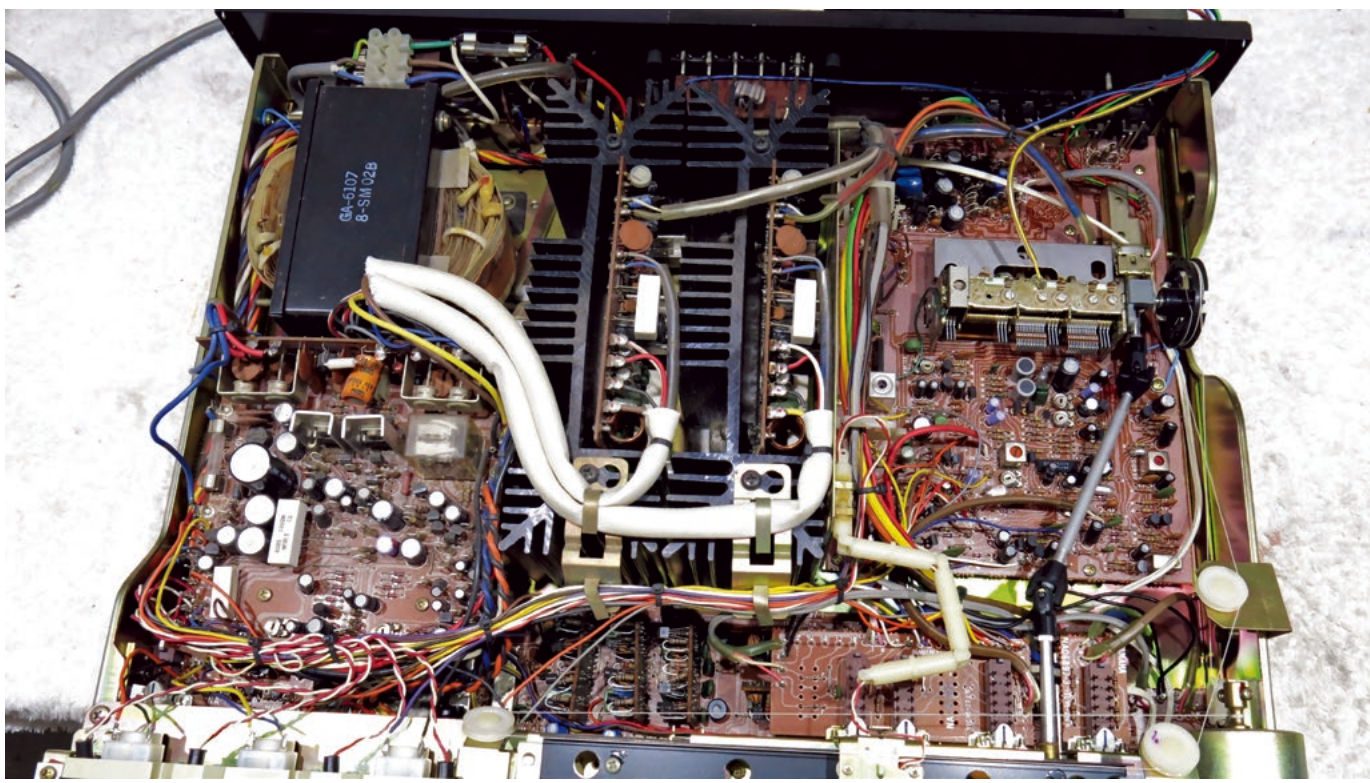
The replacement lamps arrived and fitting the new meter lamps was fairly straightforward. But the dial lamp was more tricky. It uses a Heath Robinson arrangement of articulated nylon arms which keep the wiring from the dial lamp out of the way as the pointer tracks across the dial.

I undid the two Philips-head screws that held the sliding assembly together, gently pulled it half way open without disturbing the dial cord, pulled out the old lamp, inserted the new one and put everything back together.

With a temporary capacitor in place in the power supply, I powered the unit up. The four meter lamps looked good, but the dial lamp only glowed dimly. It was only getting 4.3V due to the higher current rating of the new lamps (12V/70mA).

The dial lamp has a 180Ω dropping resistor in series, while the four meter lamps are fed from a low-impedance source. I found that adding a 560Ω 1W resistor across the 180Ω resistor gave about 10V across the dial lamp and an acceptable level of brightness.

I then turned my attention to the low 19.23V/19.6V rail. There is an apparent oddity in the circuit diagram,



The internals of the Yamaha CR-1020 amplifier, with the power supply circuit diagram shown mispelled above. You can find more details on this amp at http://www.mcqart.com/cr1020/ and http://sportsbil.com/yamaha/cr-1020-om.pdf

in that this rail feeds into diode D1, and you get 20.8V at its cathode. How does this work?

It's because there is so much ripple on the 19.6V rail that its average voltage is much lower than its peak voltage. A 1000µF capacitor at D1's cathode means that the voltage on that side is much smoother and closer to the peak voltage.

This was done on purpose, so that the speaker protection relay drops out fast when mains power is removed. This avoids nasty speaker thumps as the amplifier rails decay after switch-off. Diode D1 isolates the larger cap from the 220µF unit and stops it from prolonging the relay holding time.

I think that the high ripple current the 220µF capacitor is subjected to by this arrangement is the reason it failed. So I replaced it with a more robust 330µF/50V unit.

Accessing the underside of the relevant PCB would have been a major undertaking, so I removed the dud capacitor and soldered the new one across the wire-wrap stakes which connect to the supply rail.

Next, I decided to fix the coupler switch. Access to it proved basically impossible, so I simply gave it a good spray with isopropyl alcohol, which appeared to do the job.

I fired the amp back up, and it all worked as expected. With 237V AC mains, the output of the diode bridge was 19.0V DC, which is about right (the original specs were for 240V mains). The speaker relay pulled in firmly after its three-second delay, with its subsequent release appearing to be simultaneous with mains power switch-off, and no thumps were heard from the speakers.

I then checked the quiescent current in the power amplifiers. Working carefully, as a slipped prod can cause mayhem, I compared the test point voltages against the specification of 10mV±1mV. Both channels rose to about 14mV, so I carefully adjusted the trimpots to get 10.0mV.

With everything working well, I turned my attention to repairing the damaged veneered plywood sleeve. I dripped water onto it over more than a week, to get it to swell back out, then I sanded it and applied 'plastic wood'.

More sanding, then the application of a dark stain and finally coats of Gilly's dark restoring polish produced a remarkably good result, as seen in the photo of the restored unit below.

The quality and labour that went into this receiver is a tribute to its makers. The complicated electronics (with 109 transistors) has worked well for over 40 years, indicating a great design and execution.

The cadmium-plated chassis still gleams like new. The newly-polished timber sleeve still looks great, and the sound is still excellent.

Mitsubishi Lancer ABS pump motor repair

R. H., of North Sydney, NSW had a frustrating experience where a professional repaired the ABS (anti-skid brake) unit from his car twice, and it quickly failed again both times. He had to open it up to fix it properly himself…

On taking my Lancer for a service, the mechanic advised me that the ABS light was on and a scan revealed error code 116 (low voltage at the hydraulic pump). A better description might be "open circuit hydraulic pump motor".

A new ABS unit would cost over $3000 plus fitting. I then found out about a business which fixed ABS units. All I had to do was take the unit out and then for $350, they would service it. After which, I had to re-install it and bleed the brakes. All went well after re-installation, with no ABS light showing.

The trouble was, after about five months, the light switched on again. As the unit was still under warranty, I went through the same process again. But after re-installing it, the ABS light stayed on. A scan showed the same error code 116, and it could not be cleared, so I gave up for the time being.

Shortly after that, I found a video on YouTube showing how to fix this ABS unit. It appears that quite a few ABS units in various vehicles have the same problem.

This time, I decided to do the whole job myself. So out comes the ABS unit once again, and following the steps on YouTube, I managed to isolate the motor from the valve body. I then put an ohmmeter across the motor's terminals and it showed an open-circuit reading.

On taking the motor's case off, I found a brush hung up in its cage. It had to be gently massaged with fine sandpaper to give clearance between the brush and cage, so that it could move up and down easily. I gave the same treatment to the other brush.

On re-assembling the motor and applying power, the motor hummed away – good! Next, I had to re-assemble and re-install the ABS unit, then bleed the brakes. The ABS light remained off; wonderful! It has remained this way for a couple of years now, touch wood.

I don't understand how this problem arises. Was the retaining spring behind the brush too weak to keep it seated on the commutator? What caused the brush to lift off the commutator in the first place?

Editor's note: perhaps the car hit a big pothole which lifted it off briefly, and it got stuck.

One person on a web forum reported that he hit his ABS unit with a hammer, with a block of wood between the hammer and the valve body. It sounds a bit Heath Robinson but in hindsight, having observed the problem firsthand, it may just work; the impact could re-seat the brush back onto the commutator. SC

Home Automation

Home Automation has been the "next big thing" for quite a while now. But – with not *too* many exceptions – it remains the next big thing! Sure, there are people who have adopted Home Automation to some degree. And there are quite a few Home Automation specialist businesses set up to drag customers into the 21st century (kicking and screaming, we ask?). Well, with the new "Inventa" Home Automation Maker Plates from Altronics, that just might be about to take that giant leap forward for all mankind!

Let's face it: despite all of its promise, Home Automation hasn't exactly set the world on fire – yet! Yes, we've all heard of the family whose house "does everything", whether they're home or not, but that's the exception.

Despite the obvious advantages of returning home to a beautifully cool (or warm) house, with the dinner in the oven ready to serve, the security system going on standby after protecting the home all day . . . you get the picture, we're sure.

We believe that a major, perhaps **the** major reason for Home Automation's lack of penetration is that unless you are building a new home and can accommodate the extra cabling, extra sensors and control circuitry, it's all just too hard for the average person to get their mind around, let alone actually **do**.

We're also pretty sure that there would be a fair number of people, especially hobbyists and even more especially SILICON CHIP readers, who would like to have a go at Home Automation – if only it could be made simpler.

Enter Altronics . . . and their "Inventa" range

The Inventa series is a range of Arduino-compatible "Maker Plates" which make an easy way of adding a slick-looking user interface to a DIY home automation project. They have been designed and produced in Australia by Altronics.

We reckon they look so good that professionals will even want to use them! In addition to looking good, they're quite powerful too.

The two we're describing in this article (of the three they offer) are designed to fit into a standard Australian electrical wallplate, as might be used for a power outlet or light switch.

They are the K9660 Inventa 2.8in TFT Touchscreen Maker Plate and the K9655 Inventa 16x2 LCD Shield Maker Plate.

Both come with a pair of wallplate covers (two different styles) and standard mounting hardware. They also have headers at the back of the wallplate which can accept standard Arduino shields.

Incidentally, if all this is new to you, 'shield' is Arduino terminology for an add-on board with a specific pinout that allows it to directly piggy-back onto a main controller board, or even another shield underneath it.

It's actually the Arduino which does all the sensing, controlling and actuating and communicating –these Maker Plates are the information "interface" between the Arduino and you!

What to use them for?

The most obvious use for these Maker Plates is to create a user interface for a home automation system, allowing information to be displayed on their screens as well as accepting input via either the keypad or touch panel.

As mentioned above, "Home automation" refers to systems that control home lighting, blinds and shutters, air conditioning/ventilation appliances and so on – anything electrical that's found in the home.

Features & Specifications

Model:	TFT Touchscreen Maker Plate (K9660)	LCD Shield Maker Plate (K9655)
User Interface:	2.8in colour LCD touchscreen	16x2 character LCD with 9-key keypad
Processor:	SAM3X8E (ARM Cortex M3)	ATmega328P
Arduino compatibility:	Due	Duemilanove
Flash memory:	512kB	30kB (2kB reserved for bootloader)
RAM:	96kB	2kB
Processor speed:	32-bit, 84MHz	8-bit, 16MHz
I/O pin voltage:	3.3V	5V
Other features:	Switchmode DC regulator	Buzzer, two relays

Review/Tutorial by Tim Blythman

Made Easy(ish!)

(Left): The Inventa Touchscreen Maker Plate (K9660) is supplied mostly pre-assembled. The pre-loaded demo sketch for the TFT Touchscreen Maker Plate shows a splash screen with the Altronics logo. Such graphics are well suited to the colour screen and the powerful SAM3X8E microcontroller, which has 512kB of flash memory, useful for storing icons and other graphics.

(Right): Conversely, the Inventa LCD Shield Maker Plate (K9655) must be assembled. It is based on an ATmega328P processor and has a 16x2 display with nine pushbuttons for user control (yes, believe us – there are nine!). The interface for the LCD Shield Maker Plate reminds us of a home security alarm panel, and it would be well suited to such a role. The demo sketch shows off most of the hardware features that are built into the board.

(See the panel at the end of this article, Just what does "Home Automation" mean?).

The use of standard wallplate hardware means installing them on a wall or cabinet is very easy. These Maker Plates could also be used to add a user interface panel to an equipment enclosure, without having to worry about custom bezels and mounting.

They are also both fully-fledged microcontroller systems; both are fully compatible with the Arduino IDE (integrated development environment), and both are capable of being programmed to perform a variety of tasks.

Many standard shield-format boards can be plugged directly into the PCB to add extra functions. This could be as simple as putting some relays on a shield breakout board to automate light switching (but you'd need to be very careful to ensure safe isolation and spacing if those relays are going to switch mains!).

Or you could plug in a digital radio transmitter, Bluetooth or WiFi shield to communicate with and interface to remote devices. That would be safer as it would allow you to keep full mains isolation.

An Ethernet shield which supports power-over-Ethernet (PoE) would also be a useful addition, providing a connection into a LAN as well as power.

We'll look at the K9660 first.

Kit #1: Touchscreen Maker Plate (K9660)

While pitched as a kit, this Maker Plate does not require much assembly. In fact, by merely connecting the LCD to the main PCB, you're already in a position to load and test the supplied demonstration code.

The reason that the TFT Touchscreen Maker Plate does not require much assembly is that most of the components are SMDs and they come pre-soldered. There are a handful of through-hole parts that need to be fitted, but the bulk of the assembly is actually fitting the mechanical parts of the plate together.

There are several photos, circuit diagrams and overlays provided in the kit to assist construction, but in this article, we'll describe what you need to know to get it up and running.

The K9660 has a 2.8in touchscreen LCD (very similar to the 2.8in LCDs that we use on our Micromite projects) with an ILI9341 controller.

It also has a SAM3X8E 32-bit microcontroller, which can run at up to 84MHz. That makes it substantially more potent than your typical Arduino. It's compatible with the Arduino Due.

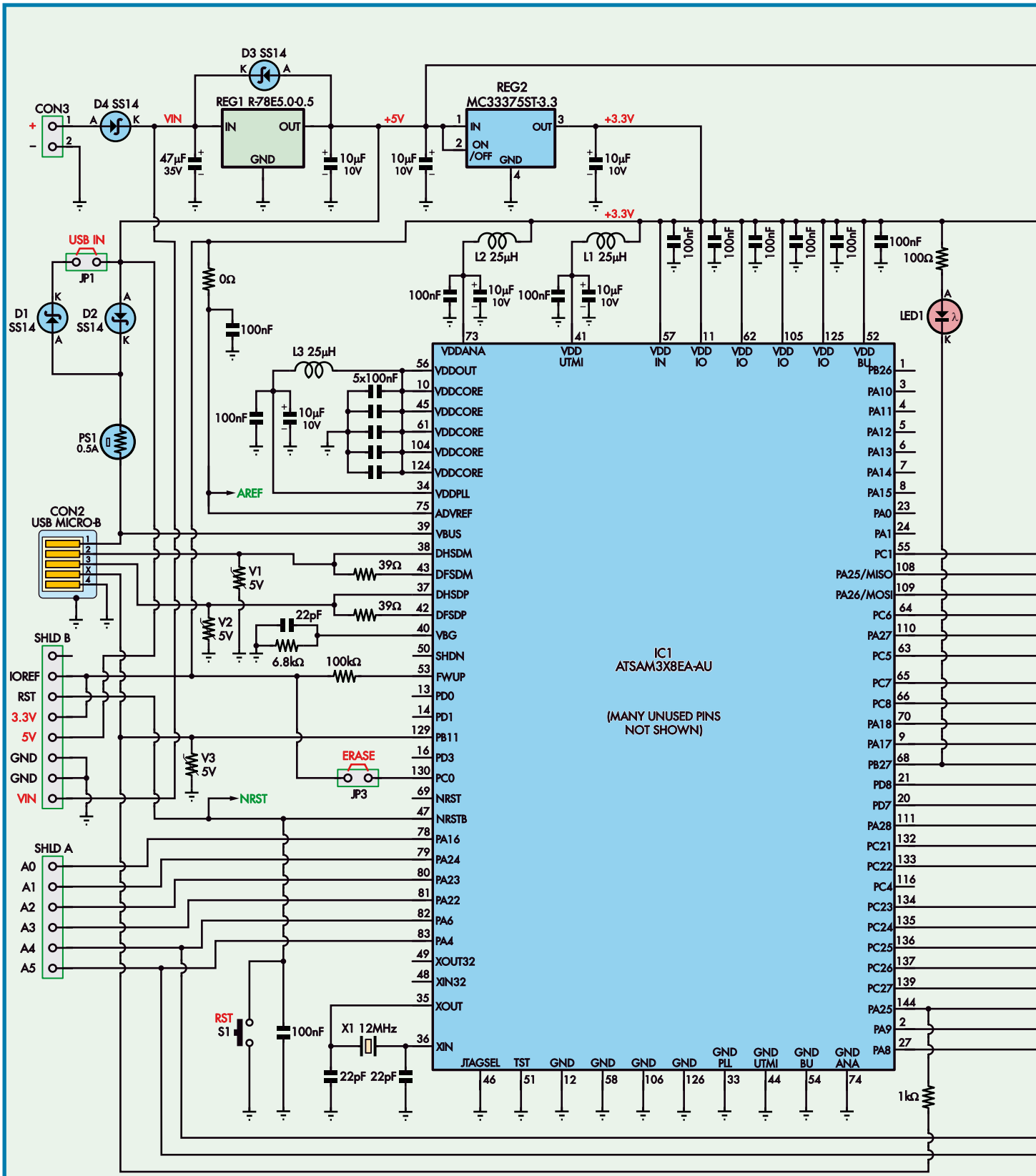
Circuit description

The circuit of the K9660 main board is shown overleaf in Fig.1. You will notice that it's dominated by the 144-pin microcontroller (IC1) and the 2.8-inch LCD touchscreen, which attaches via a 50-pin 'flat flexible' cable. PWM backlighting control is enabled by NPN transistor Q1.

This micro has an internal USB interface, and this is wired up to CON2, a micro-USB (Type B) socket. In addition to two 39Ω impedance-matching resistors for the D- and D+ lines, there are three varistors to protect the micro from static electricity, on the D-, D+ and USBID lines (V1-V3).

Power is fed in either via USB socket CON2 (through diode D1 and jumper JP1) or via terminal block CON3 and reverse polarity protection diode D4.

The 5V rail powers the touchscreen backlight and also goes to the 5V pin on the shield connector. 5V is also fed to the 3.3V regulator, REG2, which



ALTRONICS K9660 ARDUINO (ARM) TOUCHSCREEN WALLPLATE

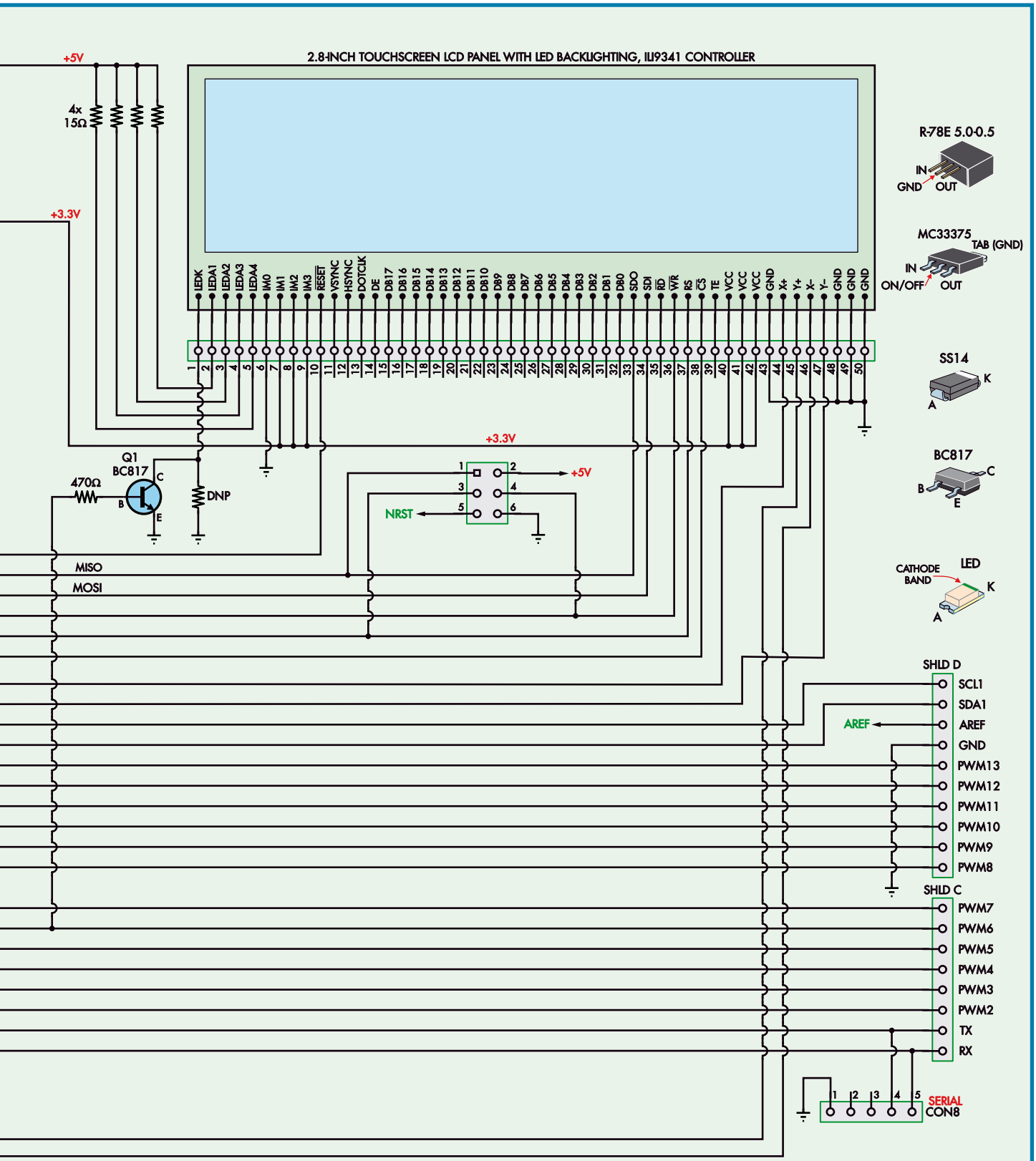
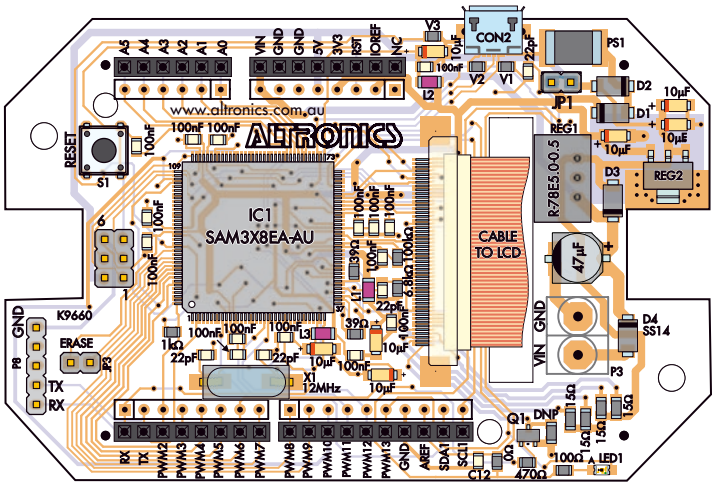


Fig.1: the Altronics Touchscreen Maker Plate is based around a 32-bit ARM Cortex processor (IC1) and a 2.8-inch touchscreen which connects via a 50-pin flat flex cable. Most of the remaining circuitry is the power supply and bypassing for IC1, components related to the USB interface plus a set of five standard Arduino R3 headers for attaching shields. This design is software-compatible with the Arduino Due.



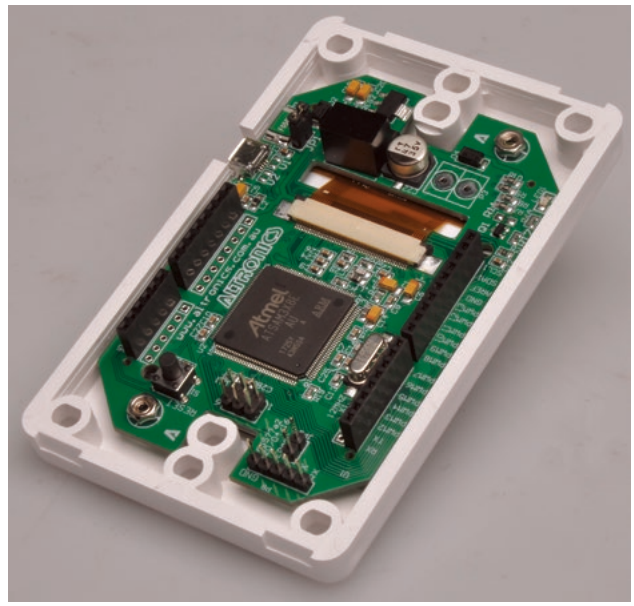


Fig.2: the Touchscreen Maker Plate board uses mostly surface-mounting parts due to the limited space, all of which come pre-soldered. You only need to fit the connectors, switchmode regulator module (REG1), reset pushbutton (S1), jumpers and terminal block. The whole thing fits neatly in a standard wallplate.

provides the logic supply for the touchscreen as well as running microcontroller IC1. It's also fed to the IOREF and 3.3V pins on the shield headers.

Two of the micro's supply pins have LC low-pass filters to reduce noise, specifically pin 73 (the analog supply) and pin 41 (powering the USB transceiver).

A third LC filter from the VDDOUT pin (pin 56) to VDDPLL (pin 34) smooths the internally generated supply voltage for the chip's phase-locked loop, which derives its 84MHz master clock from the 12MHz crystal oscillator based around X1.

Construction

Fig.2 shows the PCB overlay diagram for this project. As mentioned earlier, most of the parts come already soldered to the board. All you really need to add is regulator REG1, the headers, jumpers, screw terminals and reset pushbutton (S1).

The manual for this board explains that the standard Arduino header spacing is too wide to allow the Maker Plate to fit into a standard wall box, so two sets of headers are provided. The first is at the standard shield spacing, the second at a narrower spacing.

You can use the standard headers for prototyping but you would need to wire up the shield using jumper leads, or make an adaptor so that it can remain attached when the unit is mounted on the wall.

We suggest that you fit both sets of headers, as a mounted LCD will need to be removed to allow access for soldering. Since the LCD is fixed with double-sided tape, it could be difficult to remove.

It's best to use a spare shield as a jig to ensure that the shield headers are square and straight. Fitting the shield also gives you a chance to see what the clearances are like around the board. It's very tight, with a typical shield only barely fitting lengthwise between the mounting screw-holes in the wallplate.

A typical shield will also cover the reset pushbutton, although it is not entirely inaccessible. Many shields have their own reset buttons for this reason.

An attached shield would also foul the DC input screw terminals. As such, we elected not to fit the screw terminals. You can solder wires to its pads instead. Alternatively, you could use a lower-profile screw terminal.

After fitting the through-hole components, trim their pins to be as short as possible. This is necessary as the LCD is mounted on the back of the PCB with double-sided tape, and we need to avoid shorting out any pins on the LCD's metal shell.

Fitting the LCD is a bit fiddly, so we recommend test-fitting it without any tape to get a feel for how it all comes together. Once we were happy, we placed the double-sided tape over any exposed pins to ensure they were covered as much as possible and attached the LCD.

There is some wiggle room in the PCB's mounting holes, allowing the LCD to be centred in the bezel. Naturally, it helps to mount the LCD squarely and correctly within the marked outline.

The USB socket is accessed through a slot in the side of the wallplate; the wallplate will only attach to the PCB with one orientation because of this. We found that the thickness of the wallplate prevented some USB cables from plugging in completely, but the USB cable included with the kit worked fine.

The slot for the USB socket is covered by the decorative facia cover that is provided, so this will need to be removed to access the USB port (eg, for programming). It is possible to notch out the wallplate further if regular access is needed to the USB port.

All in all, the final product is quite tidy, but necessarily cramped. In just about all cases, a cavity in the wall or spacer block will be needed, as many of the components and headers protrude past the back of the mounting plane.

Software

The kit comes pre-loaded with a demonstration sketch programmed into the firmware, but you will need the Arduino IDE (integrated development environment) to make it do anything beyond this.

The IDE is free and can be downloaded from **siliconchip.com.au/link/aatq**

We recommend using a recent version, especially as versions after 1.6.4 include support for the automatic installation of add-on boards and libraries. We used version 1.8.5.

The Due board profile (compatible with this micro) is not installed by default, so after installing the IDE, you

will need to use the Board Manager utility to do this. Select the Tools -> Board -> Board Manager menu option, and search for "Due". Fig.3 shows how the result should look.

Click the Due entry and then click "Install". The install process will take a few moments as the toolchain components (compiler etc) are installed, after which two new entries will appear in the Tools -> Board menu.

They are "Arduino Due (Programming Port)" and "Arduino Due (Native USB Port)".

How do you power them?

Powering these Touchscreen Plates on the workbench is one thing but more than once, the question arose, "how do you power them when they're mounted in/on a wall?"

It's a fair enough question, too.

But we figured that in the vast majority of circumstances, the devices being controlled or linked to would have the appropriate power supply available – 3.3V or 5V DC as the case may be . . and it should be a simple matter to tap off the power required.

Power requirements for the Plates themselves are very modest.

In the unlikely event that this was not possible, it may be necessary to arrange an external supply (eg, a plugpack).

Working with an existing building might be problematic, but installing them in a new building should not cause significant dramas.

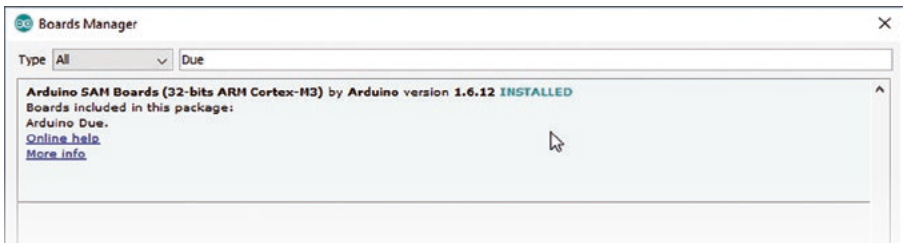


Fig.3: this shows the results of searching for "Due" in the Arduino IDE Boards manager. You need to install this Boards package to be able to program the SAM3X8E microcontroller on the Touchscreen Maker Plate board. Once you've found it, simply click on the Boards package and then click the "Install" button (not present here because we've already installed it).

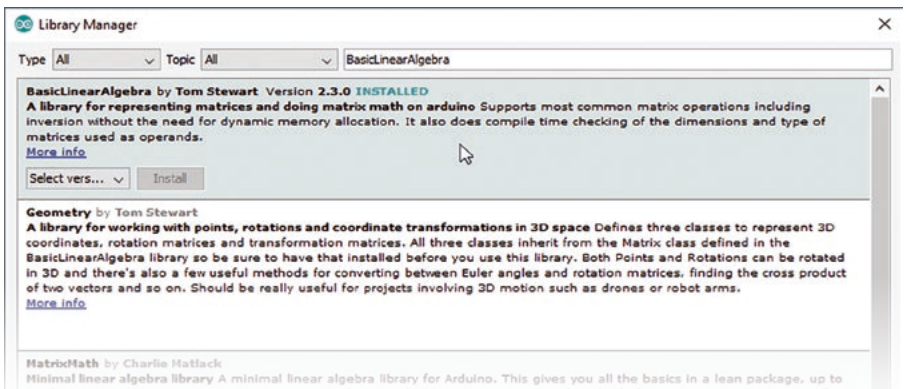

Library Manager
Type All
Topic All
BasicLinearAlgebra
BasicLinearAlgebra by Tom Stewart Version 2.3.0 INSTALLED
A library for representing matrices and doing matrix math on arduino Supports most common matrix operations including inversion without the need for dynamic memory allocation. It also does compile time checking of the dimensions and type of matrices used as operands.
More info
Select vers...
Install
Geometry by Tom Stewart
A library for working with points, rotations and coordinate transformations in 3D space Defines three classes to represent 3D coordinates, rotation matrices and transformation matrices. All three classes inherit from the Matrix class defined in the BasicLinearAlgebra library so be sure to have that installed before you use this library. Both Points and Rotations can be rotated in 3D and there's also a few useful methods for converting between Euler angles and rotation matrices, finding the cross product of two vectors and so on. Should be really useful for projects involving 3D motion such as drones or robot arms.
More info
MatrixMath by Charlie Matlack
Minimal linear algebra library A minimal linear algebra library for Arduino. This gives you all the basics in a lean package, up to

Fig.4: note the search term we've entered in the box at upper-right. The first result is one of the libraries required to compile the demo code for the Touchscreen Maker Plate. Like with the Boards files, click on the entry once located and then click the "Install" button.

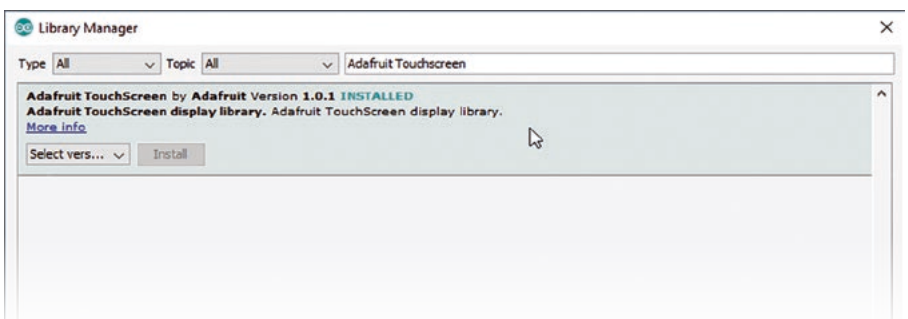


Fig.5: the second of three libraries you need to compile and upload the demo code. The third one must be downloaded separately and installed from the .ZIP file (see text for details).

While official Due boards have two USB sockets corresponding to these two entries, the Touchscreen Maker Plate only has the native USB port. This option should be selected to allow programming to occur. The correct serial port needs to be selected too (in Windows, check Device Manager).

The programming port is presumably omitted due to space constraints. The native USB port can be used for programming, but is about 30% slower.

The official Arduino advice is that the programming port is preferred, not just for speed, but because it's possible for a bug in the loaded sketch to make the native port unavailable, thus leaving you with no easy way to reprogram the chip.

Also note that the native port corresponds to the "SerialUSB" object, while the programming port corresponds to the "Serial" object, meaning that existing sketches that use the "Serial" object may need to be modified to communicate with a USB host with this board.

To compile the example sketch (downloadable from **siliconchip.com.au/link/aato**), you need three extra software libraries. Two of these can be installed by the Library Manager but the third needs to be installed manually.

The Library Manager can be found under the Sketch -> Include Library -> Manage Libraries menu. The required libraries can be found in this dialog, as shown in Figs.4 & 5. Like the Board Manager, once you've found the library, simply click on it and then click the install button.

You can download a ZIP of the third required library from: **siliconchip.com.au/link/aatp**

Once you have the file, use the Sketch → Include Library → Add .ZIP library menu item, then with the

file dialog box opens, browse to the downloaded file and click "Open". If all is well, you should see a message that the library was installed correctly.

The example sketch can now be compiled and uploaded to the board. Note that the "AltImg.h" file needs to be in the same folder as the sketch file. Uploading this sketch takes around two minutes. Most of the sketch size (and upload time) is due to the embedded graphics.

The demo sketch shows a splash screen, followed by a set of text instructions which explain the calibration process which follows. After calibration, a simple 'paint' type program allows the touch panel and display to be tested.

Hardware

Arduino pin PWM6 (physical pin 135) of the Due controller is used to control the touchscreen backlight. It can be switched on and off or dimmed. This is the only pin on the shield headers which is used for other purposes. While the Arduino version of the Due has 54 I/O pins, all of its PWM pins are already shared with the shield headers, so this was unavoidable.

Note that as the SAM3X8E microcontroller runs from 3.3V, you may find that some shields which are designed expecting a 5V microcontroller will not function properly with it.

Further software development

The TFT display library includes some more code examples. But note that those which incorporate touch sensing use a different touch library than the one which Altronics recommends, so they may need to be modified.

For the others, all you need to do to get them to work is to find their control pin definitions and change them to suit the pinout on this board, ie:

```
#define TFT_RST 33
#define TFT_DC 37
#define TFT_CS 38
```

You may also need to add some commands to the setup() function to turn the backlight on, like this:

```
pinMode(6,OUTPUT);
digitalWrite(6,HIGH);
```

The examples we tried were quite quick at updating the display, as the library uses the SAM3X8E's DMA peripheral to pass data to the screen efficiently.

The sample sketches by default do not use the native USB port for outputting their debugging data. So you should change references to the "Serial" object to read "SerialUSB" instead. A 'quick and dirty' way to achieve this is to add the following line near the top of the sketch:

```
#define Serial SerialUSB
```

For developing your own programs, we suggest using Altronics' demonstration sketch as a starting point, along with sample code from the TFT library.

Kit #2: LCD Shield Maker Plate (K9655)

The second kit is the K9655 Inventa 16x2 LCD Shield Maker Plate. It is based on an ATmega328P processor, the same one used in the Uno, although this particular design is more like the Arduino Duemilanove in operation.

It also has a 16x2 character LCD for display and a nine-button membrane keypad for input.

While it might appear from the photos that there are only five buttons, the remaining four buttons are unmarked. Along with the five marked buttons, they make up a 3x3 button grid.

The circuit for this kit is shown in Fig.6. It uses an MCP23S17 I/O expander IC to interface the ATmega328P micro to the LCD, keypad, buzzer and relays. That means that most of the regular Arduino pins are still available for use by shields.

The MCP23S17 is the SPI version of the I^2C-based MCP23017.

The circuitry at the bottom is similar to that of an Arduino Uno board, with the ATmega328P micro wired up to the usual headers, clocked from a 16MHz crystal and with a basic 5V power supply delivered by a 7805 linear regulator.

There's also a 3.3V regulator in case a connected shield needs to draw power from that pin, but it doesn't run anything else on the board.

I/O expander IC2 drives the 16x2 alphanumeric LCD module from seven of its GPA pins, configured as digital outputs. GPA6 (pin 27) drives the base of NPN transistor Q1 which connects the backlight cathode to ground, giving on/off control. Its anode is permanently connected to the +5V rail via a 200Ω current-limiting resistor.

Similarly, GPA7 drives the base of NPN transistor Q3, and this controls auxiliary SPDT relay RLY1, with its three contacts wired to terminal block CON7. So you can use it for whatever purpose you desire.

The I/O expander GPB ports are used to sense button presses on the keypad, which is arranged in a 3x3 matrix, and its six pins connect back to GPB2-GPB7 via header CON2. GPB1 drives the piezo buzzer directly while GPB0 controls another NPN transistor (Q4) which in turn switches another relay, RLY2, which has its contacts wired to terminal block CON8, again for general purpose use.

The I/O expander SPI bus is connected to the usual Arduino pins of D11-13. Other devices can share this bus. Its $\overline{CS}$ line connects to either Arduino pins D9 or D10, depending on the position of JP3. This can be used to prevent conflicts with any shields used (assuming they don't use both D9 and D10).

NPN transistor Q2 is connected to the SCK pin (D13) so that LED3 lights up when there is activity on the SPI bus. LED1 is connected across the 5V supply, so it lights up when power is applied.

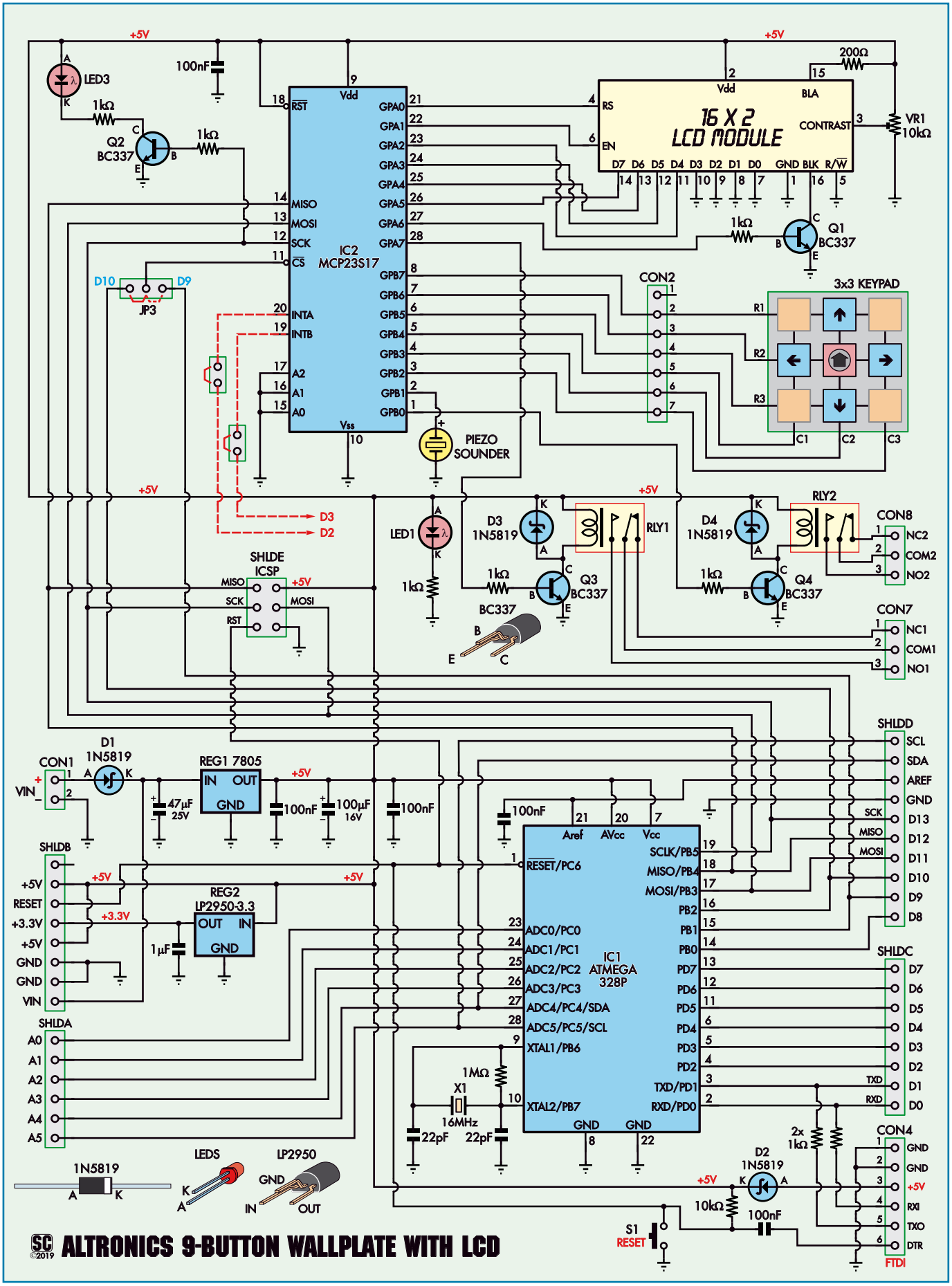
The dotted red lines shown from the INTA and INTB pins of IC2 back to D2 and D3 on the Arduino via jumpers were not present on the version of the kit we received, but will be added to future kits. With the jumpers fitted, these will allow you to trigger an interrupt routine on the microcontroller if a specific button on the keypad is pressed, without having to actively 'poll' the keypad periodically.

The board

Unlike the K9660 Touchscreen Maker Plate, this one does need to be assembled. But it's virtually all through-hole components, and not that many of them, so it isn't a big job. The PCB overlay diagram, Fig.7, shows the board layout.

The bulk of the components mount on the back of the plate. There is a

Fig.6 (opposite): the circuit for the LCD Shield Maker Plate, which is based around an ATmega328P microcontroller, the same one used in the popular Arduino Uno. I/O expander IC2 is used to interface with the LCD and keypad, so that most of IC1's pins are still available for other purposes, including connecting to one or more shields. IC2 also controls the piezo buzzer and the coils of two small relays which you can use for various purposes.



ALTRONICS 9-BUTTON WALLPLATE WITH LCD

standard Arduino R3 set of headers, including dedicated pins for I²C and SPI. There is no USB/serial converter, so serial communication and programming require a separate module. The serial header pinout matches many so-called 'FTDI' type USB-serial- converters, such as Altronics Cat Z6225.

It's quite a packed board, so much that the crystal oscillator for IC1 (an ATmega328P) is mounted on the back of the PCB. The only SMD part is IC2, and it's quite large, so not difficult to solder.

There are screw terminals for DC power in (up to 15V) and the two sets of SPDT relay contacts (for low voltage only – definitely not mains!).

Assembly

Jumper JP3 for IC2's $\overline{CS}$ connection is actually just three sets of closely spaced pads. These are hard to get at once the rest of the components have been fitted, so at this point, you should figure out which pin to use (see Altronics' instructions for more details) and bridge the two appropriate pads. We used D9 as that is the one used in the example code.

The next job is to fit the SMD IC. Make sure its orientation is correct, tack it down and then solder the pins. Clean up any bridges with flux paste and solder wick.

Then fit the remaining top-side components, starting with the shorter ones and working your way up to the taller ones.

We used an Arduino shield that we had lying around as a jig to ensure that the shield headers were mounted square and straight. Check that IC1, the diodes and electrolytic capacitors are orientated correctly, as per Fig.7.

Note the three resistors and one diode (D2) which need to be laid over to avoid fouling the wallplate surround later. REG1 and the electros also need to be mounted flush with the board.

Make sure the component leads around crystal X1's mounting position on the underside of the board have been cut as short as possible, then solder X1 in place, ensuring enough space between it and the component leads that it won't short. Adding some insulation under the crystal body is a good idea; the Altronics instructions say to use some of the supplied double-sided tape in this role, so we did so.

Their instructions also note that the pins for the LCD header are quite close together, so make sure you don't bridge any of these during soldering. If you do, use some flux paste and solder wick (and possibly also a solder sucker) to fix it.

Before fitting the PCB into the wallplate, we test-fitted the LCD and membrane pad to see that everything was working as expected. The connections for these parts are a little bit awkward, in that the sockets for both are very close. Note that the LCD connection is not keyed, so this should be checked carefully against the construction photos to ensure you plug it in the right way around.

Once the LCD is correctly connected, apply power and the demo software should start up. You can then check that the keypad buttons all work. Each press on the keypad triggers an action on the board, such as a relay toggling or the buzzer sounding.

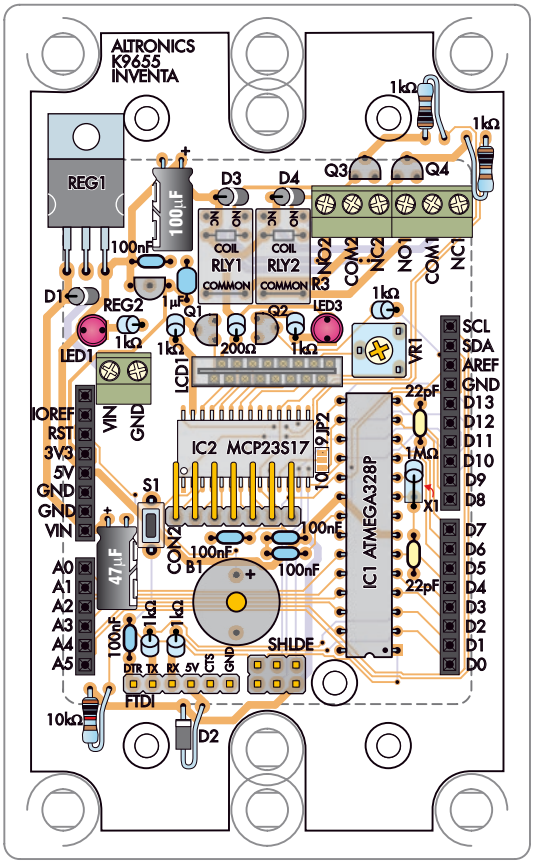


Fig.7: the LCD Shield Maker Plate comes as a bare PCB and a selection of parts. All the parts but one are through-hole types, so assembly is straightforward. CON2 is used to connect to the nine-button matrix keypad while LCD1 is a flat flex cable connector for the 16x2 LCD. The relays are not suitable for switching mains voltages as the tracks and pins are too close together, and too close to other components.

Programming connection

While Altronics Cat Z6225 FTDI USB to serial TTL adapter module could be used to program the LCD Shield Maker Plate, we tried using a CP2102-based module instead, as we stock these in the SILICON CHIP ONLINE SHOP (siliconchip.com.au/Shop/7/3543). The required wiring is shown in Fig.8.

While the CP2102 uses 3.3V logic levels, the ATmega328P can accept 3.3V digital signal levels even when running from a 5V supply. The 1kΩ series resistors on the wallplate board limit the current flowing into the serial converter RX pin to a safe level, even though the Arduino's output pin swings up to +5V.

Software

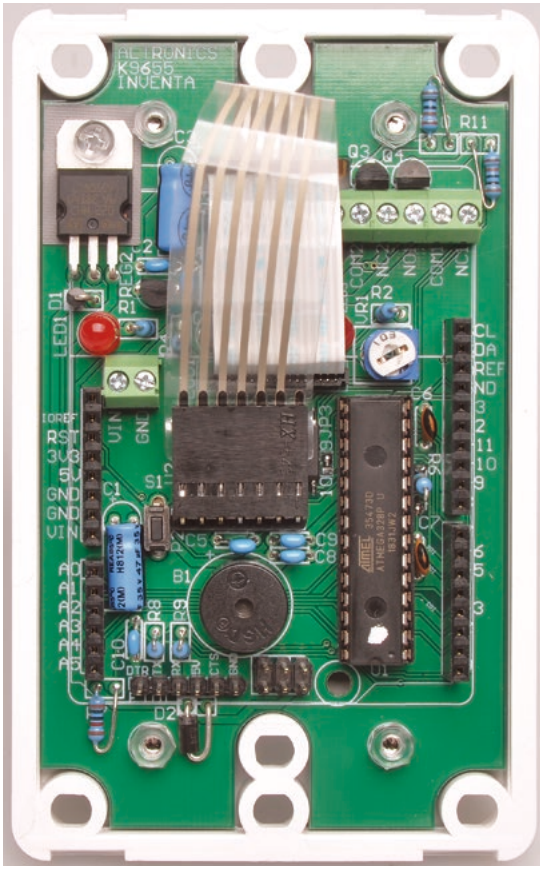
The Duemilanove processor is the same ATmega328P as used in the Arduino Uno. The main difference is that they use different bootloader firmware. The bootloader is a small piece of software that runs every time the processor starts up, to allow new sketches to be sent from the Arduino IDE to the chip.

This means that you need to select the Duemilanove board in the Arduino IDE, instead of the Uno. Otherwise, you can treat this board like the Uno.

It may be possible to change a Duemilanove to the Uno by merely replacing the bootloader, which can be done from the IDE, but you need an in-circuit serial programmer ('ICSP'). We haven't tried this, but in theory, it should provide 1.5kB more of flash programming space. It should also speed up sketch uploads. However, we have heard reports that it may not work reliably, so we recommend caution.

There are no extra libraries needed to program the demo sketch into this board (you can get it from siliconchip.com.au/link/aatr). Just make sure to extract all the files in this package to a folder named "K9655DemoCode". There are two extra files which provide functions to control the LCD, detect presses on the keypad and so on.

The Duemilanove board profile is built into the Arduino IDE, so after



selecting this and the correct serial port, we were able to compile and upload the demo sketch.

A good way to write your own code for this board is to make a copy of the demo code by using the File -> Save As menu option. This will make a copy of the K9655.cpp and K9655.h files as well as the main sketch file.

As mentioned earlier, the MCP23S17 requires a dedicated $\overline{CS}$ (chip select) pin, which can be set to either D9 or D10 using the supplied solder jumper. If your intended application requires both of these, it may be possible to solder a wire directly from the middle pad of the jumper to an alternative pin, and modify the Altronics code to use that pin instead.

Final assembly

As you might expect, the board is a very snug fit for the wallplate, and we found that we had to tweak the mounting bolts slightly to get them to fit the holes in the PCB, as well as allow the PCB to fit. The two flexible cables (for the LCD and keypad) are also a bit awkward to fit. But it makes a neat package when you manage to put it all together.

Like the TFT Touchscreen Maker Plate, either a wall cavity or spacer block will be needed, as several components protrude past the back of the plate.

Conclusion

These two Maker Plates fit a lot into a small space. The SAM3X8E processor on the TFT Touchscreen Maker Plate (K9660) is well-suited to the producing colour graphics for display on the LCD, with a faster processor and more RAM and flash memory than most Arduinos. All these features make the TFT Touchscreen Maker Plate versatile and, we think, professional looking.

However, it is significantly more expensive than the LCD Shield Maker Plate (K9655), which is better suited to more basic tasks. The more limited RAM and flash memory do limit its capabilities somewhat, but it's powerful enough for many basic applications.

To purchase, visit your local Altronics shop or order from their website at the following links (which also have more information on both products):

TFT Touchscreen Maker Plate ($175): www.altronics.com.au/p/k9660

LCD Shield Maker Plate ($84.95): www.altronics.com.au/p/k9655

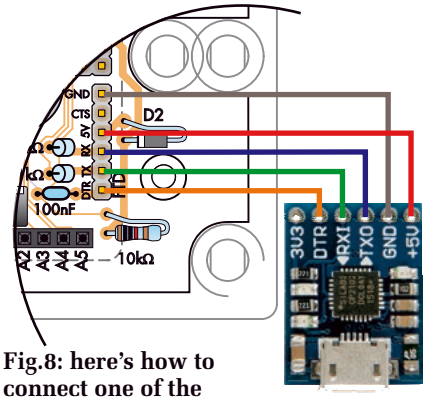
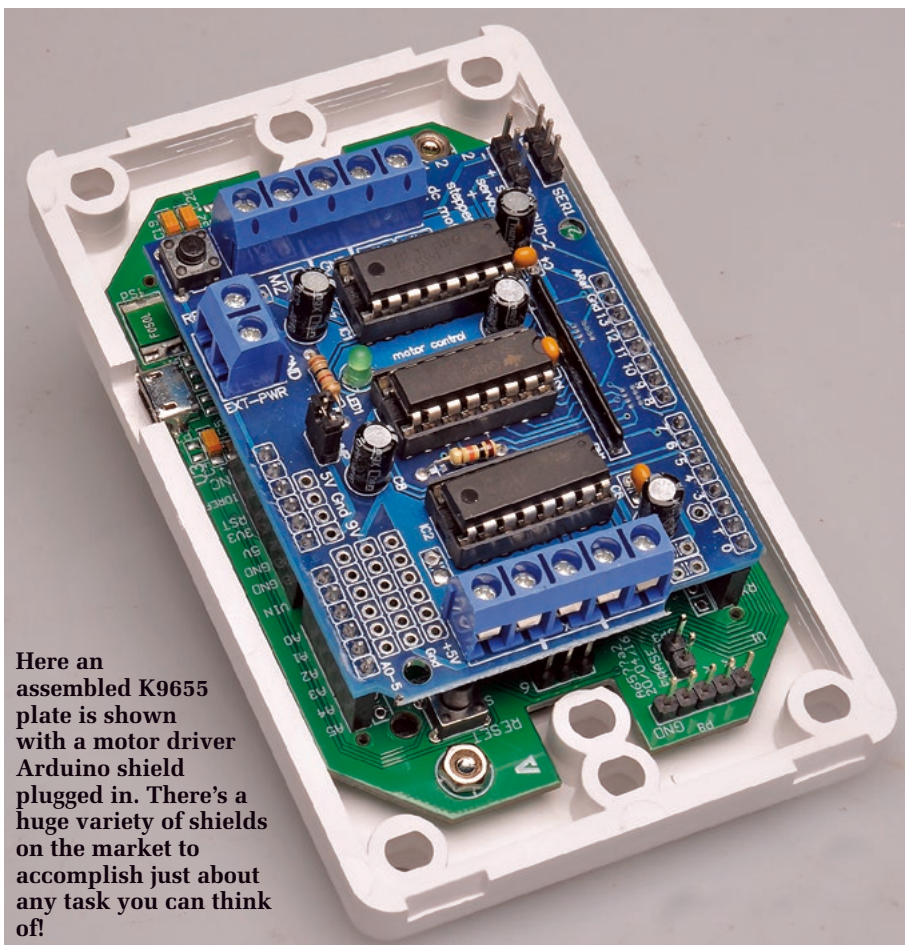


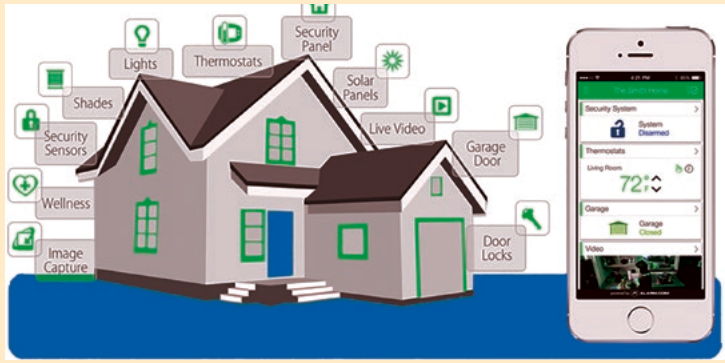
Fig.8: here's how to connect one of the ubiquitous CP2102 USB/serial adaptors, available from the Silicon Chip Online Shop (siliconchip.com.au/Shop/7/3543) to the serial header on the Touchscreen Maker Plate. This provides both serial communication between the computer and microcontroller, and allows you to upload freshly compiled sketches.



Here an assembled K9655 plate is shown with a motor driver Arduino shield plugged in. There's a huge variety of shields on the market to accomplish just about any task you can think of!

Just what does "Home Automation" mean?

It's sometimes called a "Smart Home" but either term basically means engaging technology to make the decisions required to control any, or as many of, the devices in and around a home which you normally make the decisions to control yourself.



Some of those decisions are made completely autonomously according to parameters you (or someone else) have set up. Others may require your input, either at home via some form of keypad or screen – or if you're not home, via information sent direct to your smartphone (and your decisions sent back the same way and acted upon).

Some of those "smart home" decisions, the ones often mentioned, include:

- Climate control: turning on air conditioning or ventilation to maintain a comfortable temperature – eg, heating the home when it's cold or cooling it when it's hot.
- Lighting control: turning lights on and off as required – for example, sensing whether someone is in a room and turning lights off when they're not – but also setting the lighting level you prefer.
- Blind and shutter control: you select the time or lighting conditions when you want them open or closed.
- Entertainment control: Selecting what your hifi/TV/etc system plays for you – and the level it plays at – possibly by learning what your preferences are according to the time of day.
- Security: maintaining a protection system in and around your home and reacting to any triggering it detects.
- Access control: allowing access (even unlocking and opening doors) to your home for persons who have access rights and denying it for those who don't – then choosing an appropriate course of action.
- Appliance control: turning appliances on or off according to demand, to take advantage of lower tariffs, etc.

But there are many other "things" which home automation can play a part in, such as

- Building sensors – reacting to anything outside the "norm" such as fire, flooding, gas build-up, power outages, etc.
- Personal health and safety – keeping tabs on who is at home, their health, medication reminders, baby monitors, etc.
- Pool and spa pumps and automatic chlorinators.
- Remembering – to lock the front door or close the garage when you forget (and just as importantly, NOT closing the garage door when something is in the way!).
- And even to make your home look "lived in" while you are away – and reporting to your smartphone if something is not quite right!
- Charging control: got a storage battery or maybe an electric car? You can choose when to turn chargers on, again by determining when tariffs are cheapest.

And we've really only looked at the home here – but already, "farm automation" is making huge inroads into properties, managing water resources, stock levels and locations, even farm gates and so on.

These are just some of the tasks that home automation either undertakes now or promises to undertake. (Obviously there are many more).

But just how does it/can it?

The interfaces

The big sticking point, for the "average" person, is the interface between the computers or microcontrollers that are programmed to make the smart home smart . . . and the devices which switch, or measure, or adjust, or warn, or otherwise "do" the smart tasks.

Of course, control circuitry is myriad. If you Google "home automation" or "smart home" on the net, you'll get millions, perhaps billions of hits. It might take you a while to sort the treasure from the trash but it's highly likely you'll find something to do what YOU want to do (or very close to it).

That's fine – but once again, how does the "average" person actually do it?

One of the "biggies" is that a large proportion of the home equipment lending itself to Home Automation is not only mains powered, it's hard-wired (especially in existing buildings). Think lighting, for example. And in many countries, Australia included, working on mains wiring is illegal if you don't have the appropriate licence.

Where mains devices are plug-in, it's less of a problem – though in some jurisdictions, even interfacing with those can be illegal.

This has been overcome to at least some degree by many electricians "going back to school" and learning all about smart homes and their control.

That's fine – but still leaves the hobbyist out of the loop, so to speak.

The big "IF" is that IF electrical wiring has been modified illegally and IF there is a problem (fire, for instance) not only is the hobbyist liable to be prosecuted but insurance companies may refuse to pay for any loss or damage.

The software

This is perhaps the easiest part of the whole smart home equation.

With the proliferation of microcontrollers and similar devices, there is almost certain to be software out there to do whatever you want with home automation and the smart home – or at least close to it.

Again, Google is your friend!

Even many of the projects published in Silicon Chip in recent years have code which, when you think about it, could be part of a Home Automation control system.

We're not going to dwell on the fact that you might not speak Arduino or Pi or Micromite or ..... – but it's not hard to find someone who does (especially in online forums).

Or perhaps it's time to dip your toe into the micro pool and learn what it's all about? SC

Build & Make Sale

ALTRONICS

Build It Yourself Electronics Centres®

Gear to invent, power and create!

Prices end October 31st.

Build & code your own robot with STEM Bot.

An easy to program 2 wheel obstacle avoidance and line tracking robot using the standard BBC Micro:bit software. It can be programmed to run on its own or controlled by Bluetooth. Easy to follow instruction booklet provided with simple construction. Requires 18650 lithium cell (S 4737 $19.50) & BBC micro:bit board $35.50 (Z6440).

$99

SAVE $20

Ages 8+

Z 6454

240V power from a lithium battery!

SAVE $54

$225

M 8199A

Carry 240V Power Anywhere!

This portable solar generator is fitted with 42,000mAh battery bank & 240V mains inverter. Allowing you cable free power for appliances anywhere! Plus 2.1mm DC power & USB charging. N 0040E 40W solar panel to suit $85.

Ages 8+

$59.95

K 1150

Add on a Z 6440 micro:bit starter pack for $30!

Tobbie II Robot Kit

Tobbie is back and he's had an upgrade! Powered by the popular BBC micro:bit board, this new version has unlimited scope for self programming. Front screen displays text & symbols. Requires 4xAAA batteries (S4949B).

NEW!

$44.95

D 2207

Phone Holder with Wireless Charging

Simply place your phone in the holder to keep it topped up whilst you're driving! Convenient windscreen or air vent mounting. Great for Uber drivers or road reps. Includes USB A-C cable.

Universal Aircon Remote

Lost your aircon remote? Or has your enthusiastic toddler destroyed it? This replacement works with hundreds of aircons. Requires 2xAAA batteries (S4949B).

$24.95

A 1014

SAVE 22%

$39

X 7026

Wireless Weather Station

• Indoor/outdoor temp • Humidity & air pressure • Weather forecast, moon phase, time & date. • Requires 2xAA (S4955B) & 2xAAA (S4949B) batteries.

9999 Count True RMS DMM

With in-built AC mains detection. Featuring a striking easy to read reverse backlit screen and a massive 9999 count readout. Auto ranging with easy push button operation. Great price and build quality.

$70

SAVE 22%

Q 1090

Bluetooth® BBQ Temperature Monitor

Love your slow cooked meats? Cook to perfection with the EasyBBQ dual probe monitor. All while you kick back and enjoy a coldie! Android or iOS compatible. 0-300°C range. Requires 2xAAA batteries (S4904).

$69.95

X 7015

NEW!

*Phone for illustration purposes.

Don't forget the gas! T 2451 $8.50.

$39.95

T 2486

Mini Blow Torch

A 1300°C blow torch with adjustable gas feed for a variety of tasks such as brazing and model making.

Triple USB Charger

Keep all your devices powered up in the car. 5.1A max output.

$14.50

M 8628A

Bargain Walkie Talkie Package

Amazing value for money, these walkie talkies offer a great way to keep in touch on camping trips, hiking or off-road adventures! 16 channels with charging dock. Range up to 5km.

X 0669

$79.95

SAVE $15

$95

T 2690A

30W Lithium 'Go Anywhere' Soldering Iron

45 minute run time. 600°C max. Ideal for occasional soldering jobs or light duty repairs and field servicing. Recharge by USB power adaptor in your car or at home - also recharges from a battery bank. Includes replaceable 18650 battery.

Mains Energy Consumption Meter

Monitor the real running costs of electrical appliances around the home or office. Easy in-line plugin operation.

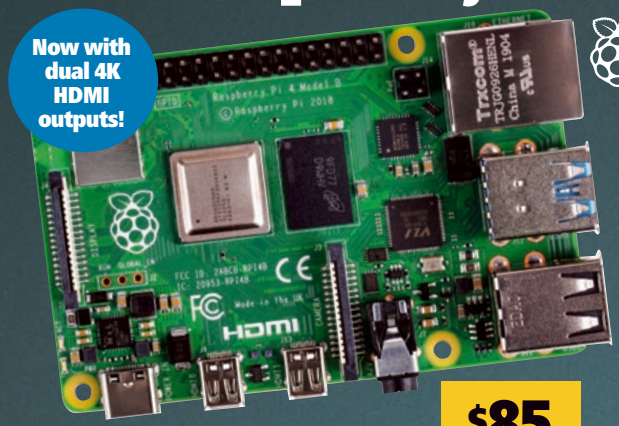
$19.95

P 8133B

See last page for store locations or visit altronics.com.au

Sale pricing ends October 31st 2019.

The parts you need to get tinkering!



The Latest Raspberry Pi® 4

The latest Pi 4 is now capable of running two monitors at once - in 4K resolution too! It's also equipped with USB 3.0, upgraded CPU and a choice of 2GB or 4GB RAM. **Micro sized desktop computing has arrived!**

$85 Z 6302E 2GB RAM

$105 Z 6302G 4GB RAM

$19.95 P 6631A 1.5m

$29.95 P 6632A 3m

Micro HDMI Cables

Connect your new Pi to your monitors with ease. 1.5m and 3m.

K 9620

Raspberry Pi® 3 Starter Platform Kit

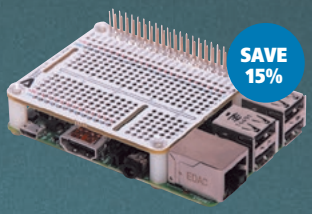
Includes a Raspberry Pi board 3 Model B, red acrylic base, 5V 3A power supply, GPIO breakout & breadboard.

$75

$14.95 H 8964 Red H 8965 Black

Raspberry Pi 4 Case

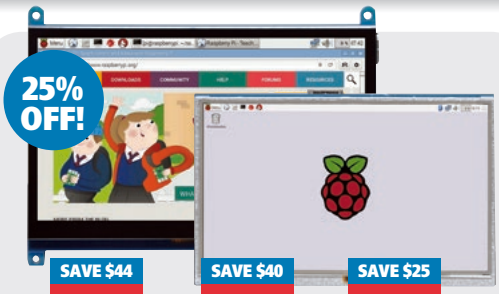
In black/grey or original red/white colours.



ProtoHAT for Raspberry Pi®

HAT board with solder-masked 0.1" holes & stackable GPIO header. Pi sold separately.

$10 Z 6307



SAVE $44 **$125** Z 6516 7" 1024x600

SAVE $40 **$99** Z 6514 7" 800x600

SAVE $25 **$74** Z 6513 5" 800x480

Large Touchscreens For Raspberry Pi®

• Great for integrated projects, mini game consoles, information stands, mini PCs etc • Works with raspbian & ubuntu • Easy HDMI connection.

2.8" Touchscreen Arduino UNO Shield

A 240x320px touch screen shield for Arduino utilising the ILI9341 chipset. 3.3/5V input.

Z 6510A

Z 6524A

128x128px TFT Display Module

A small display for a variety of applications. SPI interface with 3.3/5V input.

DIY Tinkerers Kit For Arduino

Includes an Arduino UNO compatible board, proto-shield, alphanumeric LCD, dot matrix LED module, 7 segment displays, two breadboards, stepper motor, servo, IR remote, connection leads, battery box and a variety of components, buttons and sensors.

Z 6314

Z 6381

NodeMCU ESP8266 Board

With Wi-Fi for easy plug and play connected projects. GPIO breakout pins, full USB-serial interface and pre-flashed NodeMCU in one compact package!

Z 6441

ESP8266EX Mini Wi-Fi Module

A complete and self-contained WiFi network solution that can operate independently or as a slave on other host MCUs. 3.3V input.

Z 6443

2A Lithium Charger Module

A compact module for charge management of lithium cells. Accepts 5-18V DC input, provides 4.2V charging output.

K 9615

Arduino Starter Platform Kit

A handy starter kit for educators or Arduino newbies. Includes an Arduino UNO compatible board, blue acrylic base, 5V 2A power supply, USB lead, breadboard, 65pcs of jumper leads & hardware.

Z 6467

IoT Arduino Development Board

Connect your Arduino design to the internet-of-things with this handy W5500 ethernet board with atmega328p on board. Fully UNO compatible with USB download & micro SD slot.

K 9815

ATDev Shield for ATTiny Kit

A powerful and versatile programming and breakout shield for ATtiny. Combine with a UNO for instant programmer and debugging.

J 0070

NEMA17 42 Step Motor

48BYG stepper with 1m interface lead. 5mm shaft. 12V.

Z 6442

LN298 Dual Motor Module

designed to drive inductive loads, such as relays, solenoids, DC and stepping motors. 2 channels. 5V input.

Z 6392

Lightweight SG90 Servo

A great micro servo for lightweight robotics applications. 180 degree rotation (±90°). 3.5-6V operation.

Z 6393

High Torque MG995 Servo

A high speed metal geared servo with 12kg/cm torque. Weighs 55 grams. 120 degree rotation (±60°)

Z 6444

MG90S Micro Metal Servo

A high speed metal geared servo with 2kg/cm torque. Weighs 14.5 grams. 180 degree rotation (±90°).

Top Electronics Workbench Deals.

NEW!

$599
K 8400

NEW Core I3 Desktop 3D Printer Kit

Add 3D printing to your workbench to produce working prototypes, 'one-offs' & finished designs downloadable from the internet. From printing your own gaming pieces to cosplay parts & fixes for broken parts, this printer adds versatility to any workbench. Filament roll holder to suit K 8403 $17.95.

Features: • 200x200x200 build volume • PLA filament • Pre-terminated cables for easy construction • Heated auto levelling print bed • Build time ≈3 hours.

GREAT FOR DIY ART!

$79.95
K 8300

3D Printing Pen

A crafty addition to any work space, this handheld pen extrudes 1.75mm PLA or ABS filament for decorating objects, plastic repair jobs or touch ups to 3D printed models. Easy to use with adjustable extrusion speed. Includes 12m of PLA filament.

6 colour multi colour pack of filament K 8405 $24.95

$269
SAVE $66
T 2460A

Features 3 preset channels for quick temp selection.

Micron® Touchscreen Control Soldering Station

A sturdy 100W benchtop soldering station featuring an all aluminium case and 2.8" touchscreen for quick temperature and preset selection. 100-500°C temp range with slimline handle featuring burn resistant cable.

NEW!
$27.95
T 2198B

11 Pc Screwdriver Set

Quality set of flat blade and phillips screwdrivers for general repairs. Chrome vanadium.

Wire Stripper & Kwik Crimper

Toolbox space saver!

Combines a ratchet wire stripper, cutting blade & kwik crimper (red, blue and yellow sheaths). Suits 10-24 AWG cable.

SAVE 15%
$30
T 1528A

SAVE 20%
$35
T 2171

Palm Ratchet Driver Set

A 22pc ratchet set designed for working in tight spaces. Fits in the palm of your hand, or use with a wrench handle. Includes driver tips and sockets.

SAVE 15%
$33
T 2555

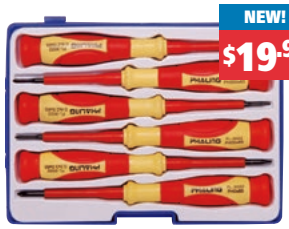
Hands free, close up viewing while you work.

Offers 1.5, 2.6 and 5.8x magnification with LED lamp. Requires 2xAAA's (S4904 $4.95 2pk).

SAVE 28%
$50
T 2175A

1000V Rated Insulated Tool Kit

Ideal for technicians working on mains powered equipment. Includes cutters, pliers, wire strippers, 5 screwdrivers plus a neon test driver and 2 rolls of insulation tape - all in a handy carry case.



NEW!
$19.95
T 2188

1000V Precision Driver Kit

Smaller sizes than most 1000V rated driver sets. Ideal for servicing AC equipment. 3 flat blade (2.0, 2.5 & 3mm) and 3 phillips (#000, #00, #0).

SAVE 27%
$29
T 2186A

101 Pc Ratchet Driver Kit

A tool for every occasion! Features 95 security, philips, pozi and slotted bits made from tough S2 alloy. Includes two way ratchet handle with comfy rubber grip. See web for full contents list.

Installer favourite!

SAVE $36
$129
T 2174

Specialist Coaxial Crimper Kit

Crimps virtually any type of coaxial RF connector! All metal crimp tool includes 5 sets of jaws to suit BNC, F, TNC, N, PL259, PAL & SMA. Strippers and cutters also included.

Tool Super Savers.

SAVE $30
T 1295
$79

Whisk Away Smelly Fumes

Tired of coughing on soldering fumes when soldering? This compact fume extractor whisks away smoke & filters the air. All metal - built to last. Spare filters, T 1291 $13.60.

SAVE 28%
T 5000
$39

Super Sturdy Tool Case

Aluminium panels with reinforced corners & seams. Locking latches. Perforated inner foam. 330x230x90 mm.

T 2282
$10
SAVE 28%

The Pocket Hero is here!

This nifty 12 in 1 pocket sized saviour helps you fix life's little problems then folds up to the size of a pack of gum! Includes belt pouch.

SAVE 14%
T 1450
$10.50
$17
T 1460 Magnifier

Handy Desktop Holders

The hobbyists dream - just like having an extra hand to get things done! Great for gluing, painting or soldering.

Secure your home and a great deal!

REDUCED FROM $899
SAVE $400
$499
S 9900H 4 Domes
20 SYSTEMS ONLY AT THIS PRICE!
Why settle for just HD? This system features 2K detail and clarity.

Affordable 4 Megapixel CCTV Surveillance System.

Simple to install with instructions supplied. Cameras can be remote viewed on iOS/Android. Each pack includes: • HD digital video recorder • Pro grade 4MP resolution weatherproof cameras • 20m connection leads • Power supply • **HARD DRIVES TO SUIT:** 1TB $110 (D 5514), 2TB $155 (D 5516).

4 Channel Wireless CCTV System

Add security to your home or business with our high resolution 4 megapixel (1080p) CCTV pack. Wireless cameras cut down installation time and effort! Pack includes power supplies for each camera, a network video recorder (expands to 9 channels) and four compact bullet cameras.

S 9442
$189

Add on an MicroSD card 16GB $9.95 (DA0328).

1080p GPS WiFi Dash Camera

Protect yourself with this feature packed dash cam! 1080p footage and includes high end features such as GPS, wi-fi footage transfer, G-sensor triggering & parking mode. Theft deterrent magnetic bracket.

S 5322

Wireless Door/Entry Alert

A handy motion activated chime unit for shops to notify staff when customers arrive. Also great for driveways. 120m range. Requires 3xAAA batteries & 3xC batteries.

S 9017

TP-Link® Wi-Fi Pan/Tilt Indoor Camera

Get the full picture with 360° horizontal and 118° vertical motorised viewing. Kasa app allows easy swipe pan/tilt movements. Provides 1080p full HD video with object tracking mode and night vision.

S 9843A
$199

Includes magnetic ball & standard wall brackets

100% Cable Free HD Surveillance

The latest in CCTV surveillance - in-built battery means you don't need to run any cables! Just mount it to the wall bracket for up to 6 months of motion detect recording. When it's flat, just take it off the wall & recharge via USB. iOS and Android app provides monitoring, battery & motion detect notifications. Records to Micro SD (DA0330 64GB $24.95).

S 9138G
NEW!
$59.95

Top Value IR Bullet Camera

1080p AHD + 960H resolution. Ideal replacement or for use in a new system.

S 5308

Bargain Movement Detectors

Affordable, reliable detection for your home or business!

S 5327

Magnetic Door Chime & Alarm

Alerts you when a door or window opens with an alarm or chime. Great for notifying you when customers arrive at your business. Adhesive backed, installs in seconds! Requires 2xAAA batteries.

Outdoor Solar WiFi Camera

This 1080p "cabling free" 2MP camera is ideal for use in situations where cabling for power and video are impractical. It provides superb clarity for both day and night use. Motion detect notifications can be sent to your phone. IP66 outdoor rating with tough diecast case.

S 9845
$329

ALTRONICS

Build It Yourself Electronics Centres

Sale Ends October 31st 2019
Phone: **1300 797 007** Fax: **1300 789 777**
Mail Orders: **mailorder@altronics.com.au**

Find a local reseller at: altronics.com.au/resellers

Please Note: Resellers have to pay the cost of freight & insurance. Therefore the range of stocked products & prices charged by individual resellers may vary from our catalogue.

Western Australia
- » **Perth:** 174 Roe St 08 9428 2188
- » **Balcatta:** 7/58 Erindale Rd 08 9428 2167
- » **Cannington:** 5/1326 Albany Hwy 08 9428 2168
- » **Midland:** 1/212 Gt Eastern Hwy 08 9428 2169
- » **Myaree:** 5A/116 N Lake Rd 08 9428 2170

Victoria
- » **Springvale:** 891 Princes Hwy 03 9549 2188
- » **Airport West:** 5 Dromana Ave 03 9549 2121

New South Wales
- » **Auburn:** 15 Short St 02 8748 5388

Queensland
- » **Virginia:** 1870 Sandgate Rd 07 3441 2810

South Australia
- » **Prospect:** 316 Main Nth Rd 08 8164 3466

© Altronics 2019. E&OE. Prices stated herein are only valid until date shown or until stocks run out. Prices include GST and exclude freight and insurance. See latest catalogue for freight rates.

B 0091

For those times when near enough isn`t good enough!

PRECISION "AUDIO" SIGNAL AMPLIFIER

There's a law in electronics which says you can *never* have too much test equipment. Even if it is pretty specialised; even if you only need it once every blue moon, there will come a time when you *do* need it! This one fits the bill perfectly: you're not going to need it every day . . . but when you do, you'll thank your good sense that you *do* have one on hand!

So what are we talking about? It's a Precision "Audio" Signal Amplifier. It's used when you need to know – exactly – what "audio" signal you're dealing with.

"Audio" is in quotes because it will actually handle signals way below the normal audio range (down to just 6Hz) and it can go all the way up to more than 230kHz . . . or even higher.

Talk about the proverbial "DC to Daylight" amplifier . . . this one is not far off!

It can deliver a particularly impressive 30V peak-to-peak (10.6V RMS) up to around 230kHz. It has two switched gain settings of either 1.00 times (0dB) or 10.000 times (+20dB), and it's powered from a standard 12V AC plugpack.

OK, so why would you want one?

Let's say you've built some audio gear and want to check it out properly. Or maybe, you need to accurately calibrate other test gear.

Or perhaps (and we imagine this will be the biggest market) you're in the service game and need to troubleshoot a misbehaving unit.

You may already have a low-cost waveform generator (there are many on the market these days) and they are increasingly built into DSOs.

They can usually generate sine, square, triangle and often 'arbitrary' waveforms with varying frequencies and amplitudes.

But the maximum amplitude is usually limited to about 5V peak-to-peak and often, that simply isn't sufficient.

This project overcomes that limitation. It can be connected to the output

By Jim Rowe

of the waveform generator to provide exactly ten times gain, boosting the signal level to just over 10V RMS.

And because the gain applied is very precise, you don't need to check the output level. You just set the generator to produce a waveform with 1/10th the needed amplitude and the signal amplifier does the rest.

I came up against this problem when calibrating our new Digital Audio Millivoltmeter, described starting on page 42 of this issue.

I have a few signal generators, but none of them could produce a sinewave with sufficient amplitude to calibrate its "HIGH" range. So I decided to design and build this precision amplifier, to generate accurate signals of a high enough amplitude for me to calibrate it.

And I realised just how useful this would be for other audio projects! It provides a choice of two accurately known gain ranges (1:1/0dB or 1:10/+20dB), over a relatively wide range of frequencies, from 20Hz up to beyond 200kHz.

Features & specifications

Input impedance: 100kΩ//9pF
Output impedance: ..... 51Ω (each output)
Gain: ..... A=1 (0dB) or A=10 (+20dB)
Frequency range: (see Fig.1) ..... For A=1: 6Hz to >1MHz (+0,-0.3dB)
..... For A=10: 20Hz to 230kHz (+0,-0.3dB)
Maximum input signal level: .... For A=1: 10.6V RMS (+20.5dBV)
..... For A=10: 1.06V RMS (+0.5dBV)
Maximum output signal level: .. 10.6V RMS (+20.5dBV)
THD+N: ..... For A=1: 0.0007% (-103dB)
..... For A=10: 0.007% (-83dB)
Power supply: ..... 12V AC at <100mA

Circuit details

The Signal Amplifier circuit is shown in Fig.2. As you can see, the amplifier itself (lower section) is quite straightforward.

That's because we are using a rather special op amp, the Analog Devices ADA4625-1 (IC1).

It offers very high input resistance, thanks to the use of JFET input transistors. It has a typical gain-bandwidth product of 18MHz, very low noise, fast settling time (to within 0.01% in 700ns), a rail-to-rail output swing and the ability to operate from a 'single supply' of up to 36V.

Other features include a low output resistance in closed-loop mode (typically 2Ω when gain=1 or 18Ω when gain=10) and the ability to drive load capacitances up to 1nF in closed-loop unity-gain operation.

We are using IC1 in a standard non-inverting configuration, with the input signal from CON1 coupled to its non-inverting input (pin 3) via a 1µF metallised polyester capacitor.

The output from IC1 is then fed to output connectors CON2 and CON3 via another 1µF metallised polyester coupling cap, with a 51Ω protective (and impedance-matching) resistor in series with each connector.

Switch S1 is used to alter the feedback around IC1, to provide either unity gain or a gain of 10.

In the A=10 position, the 100kΩ 0.1% resistor forms the top arm of the feedback divider, while the lower arm is formed by the series combination of the 10kΩ and 820Ω fixed resistors together with VR1, a 15-turn 500Ω trimpot.

The trimpot allows us to set the amplifier's gain to exactly 10.000, by compensating for within-tolerance variations in the value of the 10kΩ and 820Ω resistors (both 1% tolerance) as well as the 100kΩ 0.1% tolerance resistor.

Although it's easy to calculate the nominal lower-arm resistance for a gain of 10.000 (it's 11.111kΩ), this would need to be made up from at least two more 0.1% tolerance resistors (11.0kΩ and 110Ω), to give a gain of 10.0009 with a tolerance of +0.018% and -0.0162%.

By using two 1% tolerance resistors and a 15-turn trimpot, we can achieve even better potential accuracy at a significantly lower cost.

But how do you set the gain to exactly 10.000? You just need a relatively accurate DMM. You measure the value of the 100kΩ 0.1% resistor (which should be between 99.9kΩ and 100.1kΩ), then divide that by nine, and adjust VR1 so that the total lower-arm resistance matches the calculated value (which should be close to 11.111kΩ).

The upper part of the circuit exists primarily to generate a 32V DC supply voltage from the 12V AC plugpack, so that IC1 can deliver output signal amplitudes as high as 30V peak-to-peak or 10.6V RMS.

This is achieved in two stages. First, diodes D1 and D2 and the two 470µF capacitors form a simple 'voltage doubler' rectifier configuration, which derives about 38V DC from the incoming 12V AC.

This is followed by voltage regulator REG1, an SMD version of the familiar

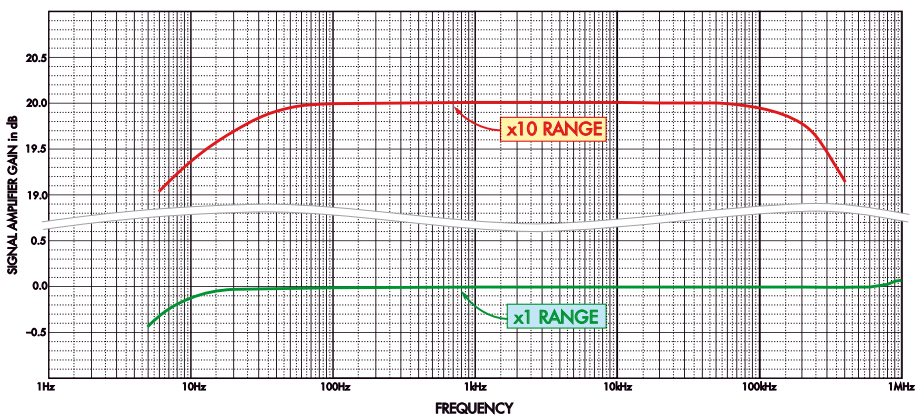
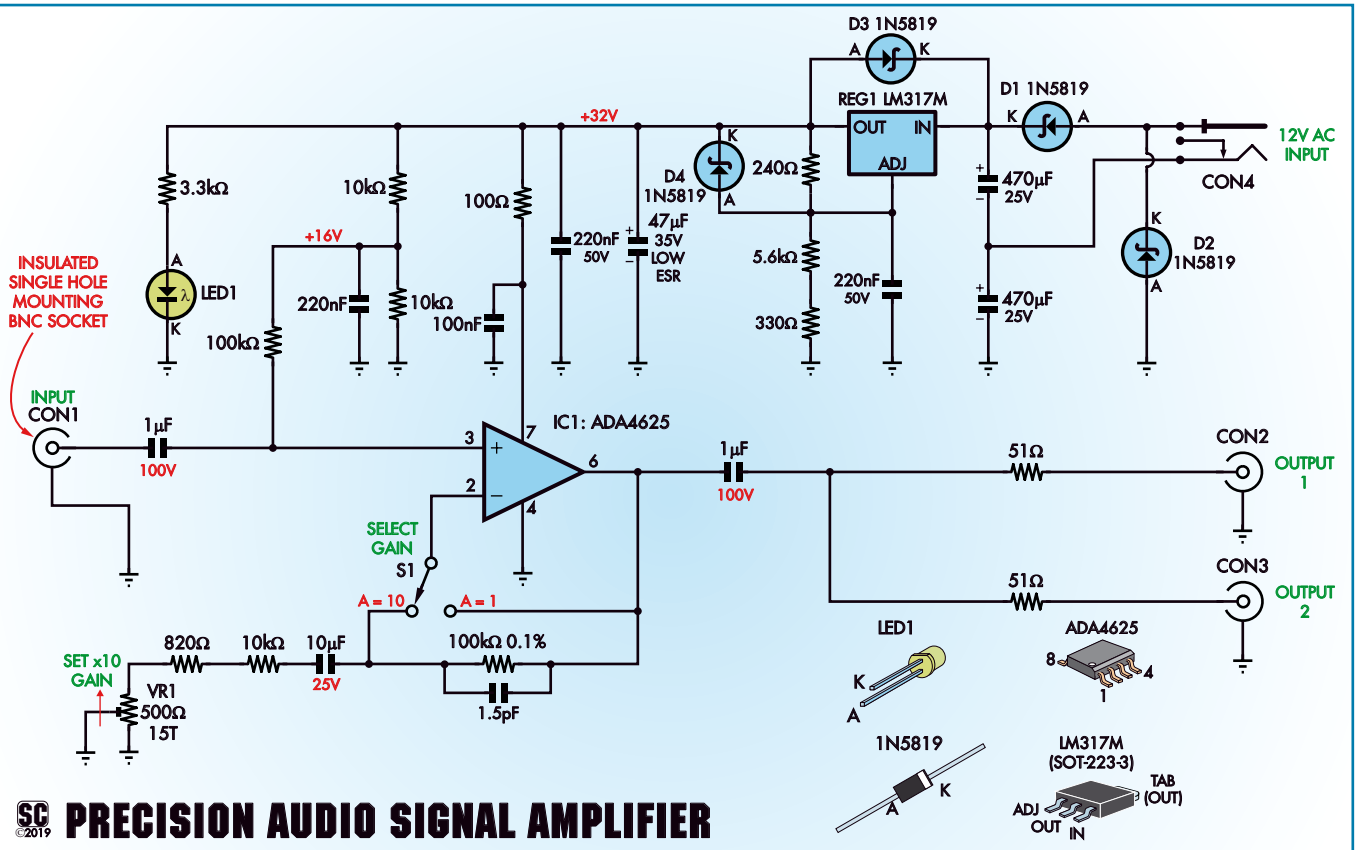


Fig.1: this shows a frequency response plot for the Signal Amplifier at both gain settings. The response in both modes is entirely flat from 100Hz to 50kHz, so ideally, calibration and measurements should be made within that range. But it gives acceptable performance (within 0.3dB) from 20Hz to 230kHz, which more than covers the audio range.



PRECISION AUDIO SIGNAL AMPLIFIER

Fig.2: the Signal Amplifier circuit is based around precision JFET-input op amp IC1 and uses a precision resistor and trimpot to provide a very accurate 10 times gain (+20dB), to boost the level of signals from devices such as arbitrary waveform generators. The 12V AC supply is boosted and regulated to 32V DC using a full-wave voltage doubler configuration (D1 & D2), followed by a low-ripple adjustable linear regulator (REG1).

The SILICON CHIP Inductance - Reactance - Capacitance - Frequency READY RECKONER

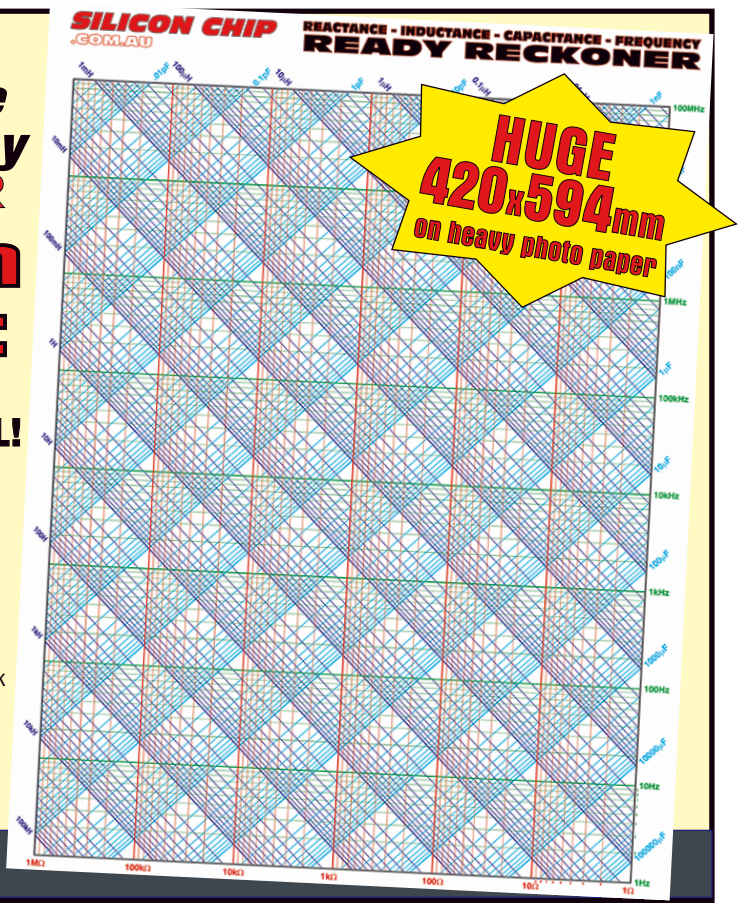
For ANYONE in ELECTRONICS:

You'll find this wall chart as handy as your multimeter – and just as ESSENTIAL!

Whether you're a raw beginner or a PhD rocket scientist . . . if you're building, repairing, checking or designing electronics circuits, **this is what you've been waiting for!** Why try to remember formulas when this chart will give you the answers you seek in seconds . . . easily!

Read the feature in the January 2016 issue of SILICON CHIP (*you can view it online*) to see just how much simpler it will make your life! All you do is follow the lines for the known values . . . and read the unknown value off the intersecting axis. It really is that easy – and quick (much quicker than reaching for your calculator!

- **Printed on heavy (200gsm) photo paper**
- **Mailed rolled in tube for protection**
- **Limited quantity available**



Mailed Rolled in Tube: Just $20.00 inc P&P & GST

ORDER NOW AT www.siliconchip.com.au/shop

Parts list – Precision Signal Amplifier

1 double-sided PCB, code 04107191, 92 x 51mm
1 diecast aluminium box, 111 x 60 x 54mm [Jaycar HB5063]
1 12V AC plugpack (100mA or higher) with 2.1 or 2.5mm plug
1 SPST mini toggle switch (S1)
1 insulated BNC socket, single hole panel mounting (CON1)
2 BNC sockets, single hole panel mounting (CON2,CON3)
1 PCB-mount concentric DC socket, 2.1mm or 2.5mm inner diameter (to suit plugpack) (CON4)
4 25mm long M3 tapped spacers
8 M3 x 6mm panhead machine screws
2 1mm PCB stakes (optional)
9 30mm lengths of hookup wire (to connect S1 & CON1-3 to the PCB)

Semiconductors
1 ADA4625-1ARDZ low-noise JFET input op amp, SOIC-8 SMD package (IC1)
1 LM317M adjustable voltage regulator, SOT-223-3 SMD package (REG1)
4 1N5819 40V 1A schottky diodes (D1-D4)
1 3mm green LED (LED1)

Capacitors
2 470µF 25V RB electrolytic
1 47µF 35V RB low-ESR electrolytic
1 10µF 25V multi-layer ceramic (X5R 3216/1206 SMD)
2 1µF 100V polyester (radial leaded)
3 220nF 50V multi-layer ceramic (X5R 3216/1206 SMD)
1 100nF 50V multi-layer ceramic (X5R 3216/1206 SMD)
1 1.5pF 100V multi-layer ceramic (C0G 1206 or 0603 SMD)

Resistors (1% all SMD 3216/1206 SMD unless otherwise stated)
1 100kΩ 0.1% 0.25W axial leaded
1 100kΩ 3 10kΩ 1 5.6kΩ 1 3.3kΩ
1 820Ω 1 330Ω 1 240Ω 1 100Ω 2 51Ω
1 500Ω 15-turn horizontal trimpot (VR1)

LM317 adjustable regulator. Here it's configured to provide a regulated output of 32V which is fed to IC1 via a 100Ω resistor.

The 220nF capacitor from the ADJ (Adjust) pin to ground improves its ripple rejection, which is helpful here as with the voltage doubler configuration, each filter capacitor only recharges at 50Hz.

The 32V rail is also used to provide a 'half supply voltage' bias of 16V for the non-inverting input of IC1, via a 10kΩ/10kΩ resistive divider with a 220nF ripple filter capacitor.

LED1 is a power-on indicator, connected to the +32V line via a 3.3kΩ series resistor.

Construction

Almost all of the circuitry and components are mounted on a single PCB which fits inside a diecast aluminium box, for shielding.

The PCB measures 92 x 51mm and is coded 04107191. Refer now to the overlay diagram, Fig.3, along with the matching photo.

The only components not mounted on the PCB are input and output connectors CON1-CON3 and range selection switch S1. These all mount on the box lid/front panel, with short lengths of hookup wire linking them to the PCB.

It's easiest to fit the SMD components to the PCB first, starting with the passives (resistors and capacitors) and then REG1 and IC1.

Make sure IC1's pin 1 dot/divot (or bevelled edge) is orientated as shown in Fig.2.

Then fit the leaded parts, starting with the 100kΩ 0.1% resistor and diodes D1-D4 (with the orientations as shown), trimpot VR1, the two 1µF capacitors, the two 470µF and 47µF electrolytic capacitors (longer lead towards + sign) and then the power input connector, CON4.

The final step is to fit LED1, which is mounted vertically just below the centre of the PCB.

First solder a 2-pin SIL header to the PCB, then solder the LED's leads to the header pins, with the LED anode towards the front.

The underside of the LED body should be about 24mm above the top

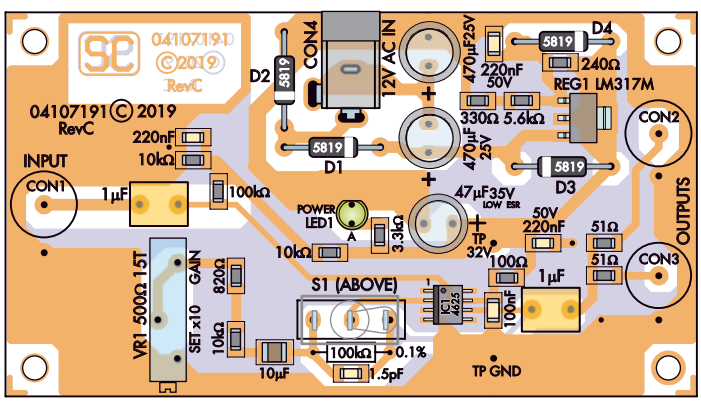
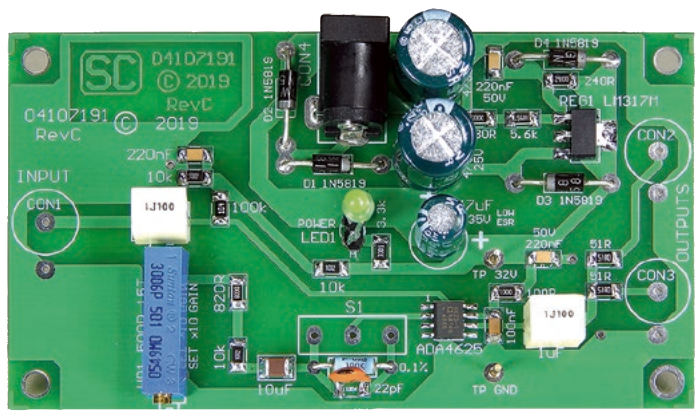


Fig.3: all of the components mount on this PCB, except for CON1-CON3 and switch S1. The design uses a mix of through-hole and surface-mounting parts. Fit them where shown here, being careful to ensure that IC1, LED1, diodes D1-D4 and the electrolytic capacitors are mounted with the correct polarity.



And here's the almost-complete PCB immediately before final assembly. Naturally, S1 and the connectors are not yet fitted because these mount on the front panel and connect to the PCB via short wire links. The PCB "hangs" off the front panel via 25mm M3 tapped spacers, which are screwed to the four holes in the PCB corners.

of the PCB. This will allow it to protrude through the box lid/front panel when the unit is assembled.

Your Signal Amplifier PCB is then virtually complete. The next step is to set the gain of its 10x/20dB range. Use a DMM with the best resistance accuracy possible.

Monitor the resistance between the junction of the 10kΩ resistor and 10µF capacitor near VR1, and the PCB's ground. Then adjust trimpot VR1 until this resistance is as close as possible to one-ninth the resistance of the 100kΩ 0.1% resistor.

If you're not confident of your DMM's accuracy, it may be easier to simply adjust the lower arm's resistance to measure 11,111Ω (11.111kΩ, or 100kΩ÷9).

But if you can measure both values on the same range, any proportional inaccuracy in the DMM itself should be cancelled out as it applies to both measurements.

It's now time to test the completed PCB by connecting a source of 12V AC, such as an AC plugpack. LED1 should light up.

Measure the voltage between TP 32V and TP GND. You should get a reading close to 32V. If so, you can disconnect the power lead and put the PCB aside while you work on the box.

Preparing the box

This is fairly straightforward. It involves drilling a total of nine holes in the box lid/front panel, another hole in the front of the box itself and then a larger hole (12mm diameter) in the box rear.

The locations and sizes of all these holes are shown in the cutting diagram, Fig.4.

After all of the holes have been drilled, cut and de-burred, you can attach a dress front panel to the lid, to give the Signal Amplifier a neat and user-friendly look. You can copy the front panel artwork shown in Fig.6, or download is a PDF file from the Silicon Chip website.

Then you can print it out and laminate it in a protective pouch to protect it from getting soiled.

It can then be attached to the box lid using double-sided adhesive tape. The final step is to use a sharp hobby knife to cut the holes in the dress panel, to match those in the lid underneath.

Now fit the three input and output BNC connectors to the front panel, along with switch S1, and then turn the panel over and solder short lengths of insulated hookup wire to the rear connection lugs of the connectors and S1.

Next, attach the four 25mm-long M3 tapped spacers to the corners of the front panel, using four 12mm long M3 screws. Then you can cut the hookup wires soldered to CON1-CON3 and S1 to a length which will enable them to just pass through the PCB holes when the board is attached to the rear of the spacers.

Remove about 6mm of insulation from all of the wire ends, so that they can be easily soldered to the matching PCB pads.

After bending these wires so their ends are positioned to meet with the holes in the PCB, offer up the PCB

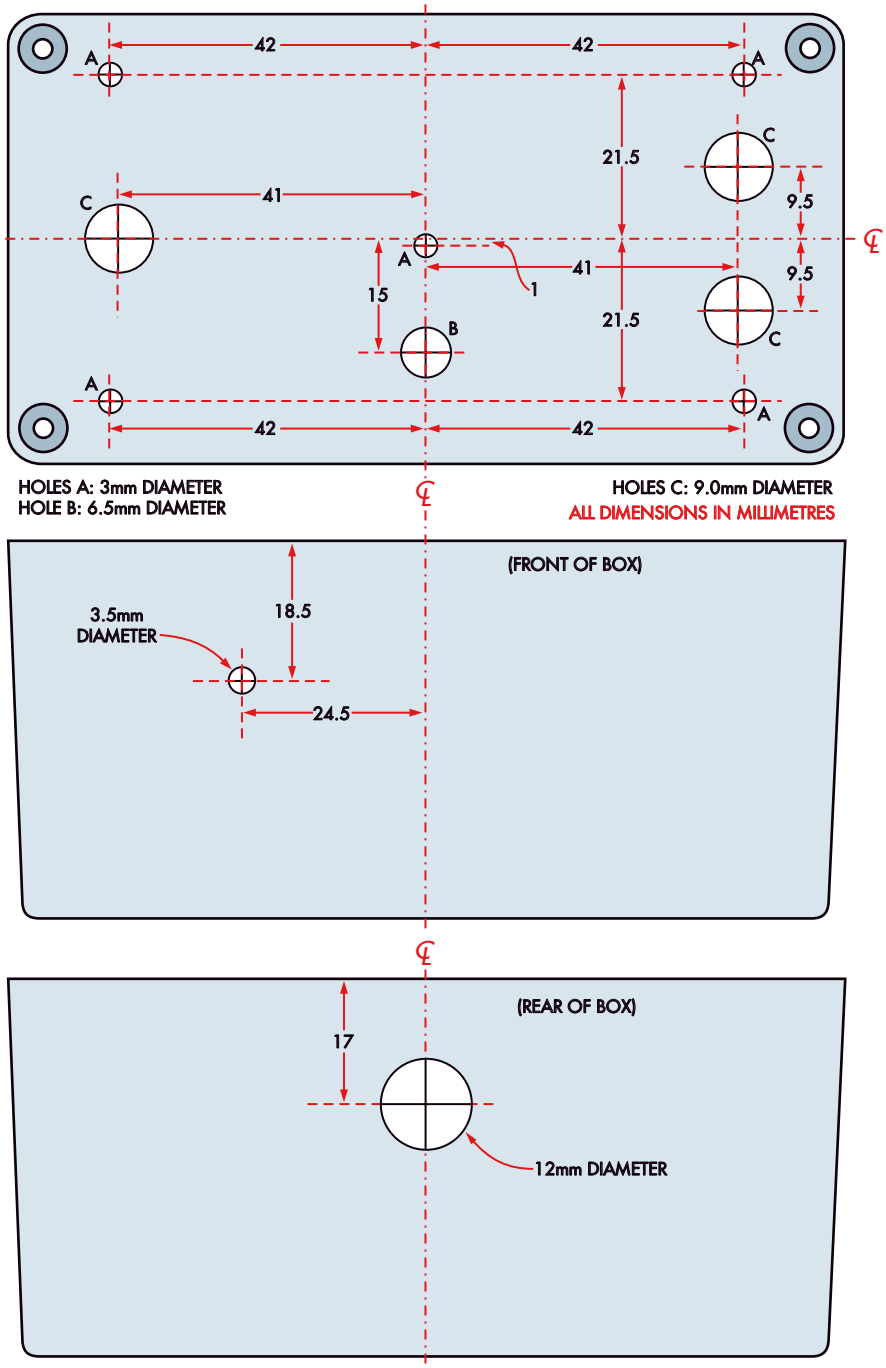
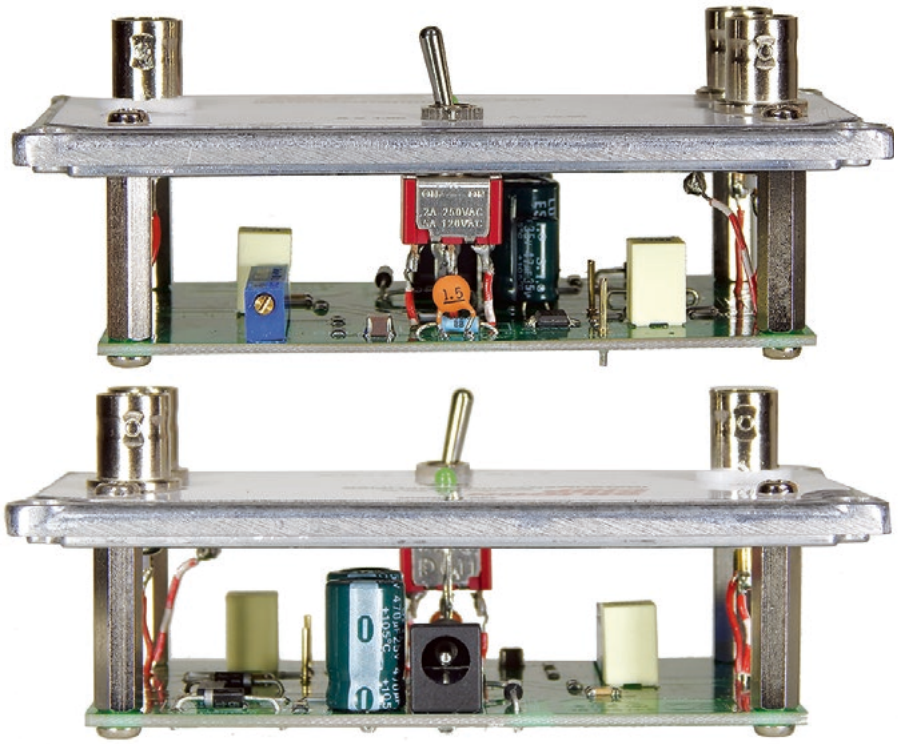
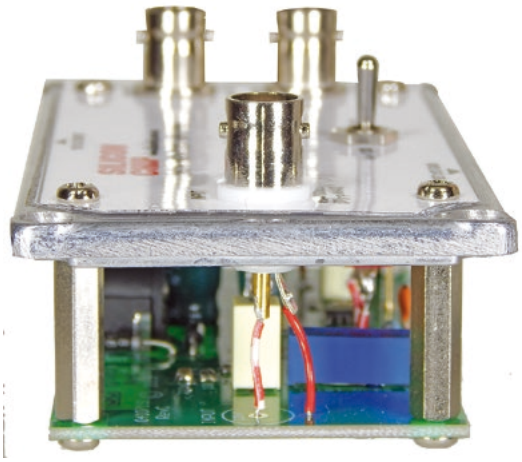


Fig.4: here are the locations and sizes of the holes that need to be drilled in the diecast aluminium enclosure. For the larger holes, it's best to start with a smaller pilot hole (eg, 3mm) and then enlarge it to size using either a stepped drill bit, a series of larger drills or a tapered reamer. That ensures accurate positioning and a clean, round hole. You can copy this diagram and attach it to the box using tape to use it as a template



Above are two views of the assembled unit from the front (top) and the rear (bottom).



And here's an end-on view from the input end. x10 gain is calibrated via the multi-turn pot (blue component) in the foreground.

assembly to the spacers on the rear of the panel.

With a bit of jiggling, you should be able to get all of the wires to pass through their matching holes. You can then attach the PCB to the spacers using four more 6mm long M3 screws, up-end the assembly and solder each of the wires to its PCB pad.

Your Signal Amplifier is now complete, and should look like the one shown in our photos.

All that remains is to lower the lid-and-PCB assembly into the box and fasten them together using the four M4 countersunk-head screws supplied with it.

Checkout & use

At this stage, your Signal Amplifier should be ready for use. Remember that it can deliver a maximum output voltage of 30V peak to peak or 10.6V RMS, assuming that it is feeding a high-impedance load, of 50kΩ or more.

If the load impedance is much lower, the maximum output amplitude will be slightly reduced.

Note that you can check and even adjust its calibration even after it has been sealed in its box. To do this, you will need an audio oscillator or function generator and a DMM with true-RMS AC voltage range with reasonable accuracy and resolution.

Set your oscillator or function generator to produce a sinewave at 1kHz and around 1V RMS, then connect its output to the input of the Signal Amplifier. Then connect your DMM's input to one of the Signal Amplifier outputs.

With the Signal Amplifier's gain set to unity (A=1), power it up and your DMM should indicate an AC voltage very close to 1.00V. If not, you may need to tweak the output of your oscillator/generator until this reading is achieved.

Then all you have to do is select the Signal Amplifier's x10 range, whereupon the DMM reading should jump to 10.000V, or very close to it. Adjust trimpot VR1 with a small screwdriver or alignment tool (through the small hole in the front of the box), until the DMM is reading 10.000V. SC

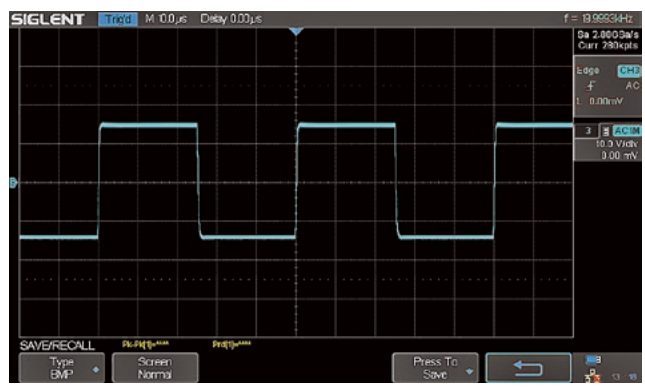


Fig.5: this scope grab of the unit's output with a full-swing (32V peak-to-peak) 20kHz square wave demonstrates the fast slew rate and quick settling time of the ADA4625 op amp. You can see that there is minimal rounding and overshoot after each transition and it settles close to the target value in well under 1µs.

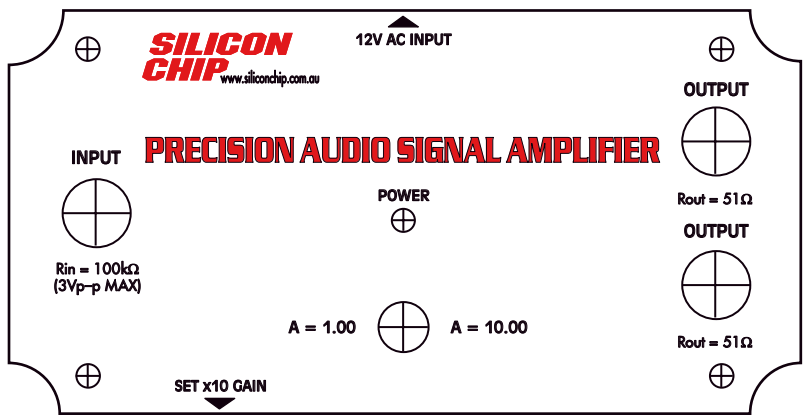


Fig.6: this 1:1 front panel artwork can be copied and fixed to the lid or can be downloaded from the SILICON CHIP website, printed and then applied.

Some people are just IMPOSSIBLE to buy Christmas gifts for!

You know the problem: you want to give a Christmas Gift that will really be appreciated . . . but what to give this Christmas?

SILICON CHIP
OCTOBER 2019
The VERY BEST DIY Projects!
NEW BENCH SUPPLY: 45V 8A
Constant Voltage • Constant Current • With digital display
TWO NEW ARDUINO NANOS
Nano 33 IoT
Nano Every
• More Powerful!
• More Versatile!
• And they cost less!
MORE TEST GEAR!
High-Res Audio Millivoltmeter
Precision Audio Signal Amplifier
They Called It "The Thing"
Read all about it - and more - inside!

We make the impossible possible!

Give them the Christmas Gift that KEEPS ON GIVING – month after month after month:

A GIFT SUBSCRIPTION to SILICON CHIP

For the technical person in your life, from beginner and student through to the advanced hobbyist, technician, engineer and even PhD, they will really appreciate getting their own copy of ***SILICON CHIP*** every month in the mail.

They're happy because they don't have to queue at the newsagent each month. You're happy because it actually costs less to subscribe than buying it each month.

- *CHOOSE FROM 6, 12 OR 24 month subscriptions*
- *Start whenever you like (Jan-Dec is very popular!)*
- *You can include a message with your gift as well – to let them know that you've thought of them!*

Ordering your gift subscription is easy!

To Place Your Order:	ONLINE (24/7)	OR	PHONE (9-5, Mon-Fri)	OR	PAYPAL (24/7)	OR	eMAIL (24/7)	OR	MAIL
	Log onto *siliconchip.com.au* click on [subscriptions] and fill in the details!		Call (02) 9939 3295 with your order (including credit card details) – and tell us who the gift is for!		Use PayPal to pay *silicon@siliconchip.com.au* Don't forget to include all details!		*silicon@siliconchip.com.au* with order & credit card details include your contact info!		All order details – including credit card details & contact no to PO Box 139, Collaroy NSW 2097

CHRISTMAS IS ONLY 13 WEEKS AWAY!

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Three Norton (current feedback) amp based sinewave oscillators

I needed a simple sinewave oscillator for a project I was working on. You might think that an operational amplifier (op amp) with two resistors and two capacitors in the feedback loop would be sufficient.

However, in practice, this doesn't work well. To get a pure sinewave with a stable amplitude, additional components such as non-linear elements or AGC (automatic gain control) need to be introduced, as is common in Wien bridge oscillator circuits.

For example, see the Wien Bridge Oscillator circuit we published on page 89 of the July 2017 issue, which uses a small lamp for amplitude stabilisation (siliconchip.com.au/Article/10725). Other designs are even more complicated than this.

As I was working with Norton operational amplifiers at the time I needed this oscillator, I considered whether it was possible to design a simple sinewave oscillator around one of them. The inputs behave like diodes, and it occurred to me that they could provide the non-linear function required for the oscillator.

After doing some mathematical calculations, I came up with circuit (a) shown here. To my delight, it worked perfectly the first time around. Further investigation showed that there were only two other 'canonical' configurations possible. All three designs are shown here, and test results are presented.

For a full mathematical analysis of these circuits, download the PDF: siliconchip.com.au/Shop/6/5073

You can build these circuits using one of the following ICs: LM3900 (National Semiconductor, now owned by TI), MC3401 (Texas Instruments) or CA3401 (RCA). These are all single-supply amplifiers and for normal operation, they need to be biased so that DC output voltage is half V_{CC}. This means that the bias resistor is equal to twice the negative feedback resistor. I used the LM3900.

For all three, the circuits frequency of oscillation is given by the following formula:

$$F(Hz) = \sqrt{1 \div (R1 \times R2 \times C1 \times C2)} \div 2\pi$$

The condition for oscillation depends on the circuit configuration and is shown below the circuit diagram. If you can't get 20nF capacitors, you can parallel two 10nF capacitors. You can use various combinations of resistors in series to get 40kΩ and 60kΩ, eg, 22kΩ + 18kΩ and 27kΩ + 33kΩ respectively.

I used 1% metal film resistors and 5% greencaps, and mostly the circuits worked well. But the three different circuits are not identical in terms of sensitivity to component values.

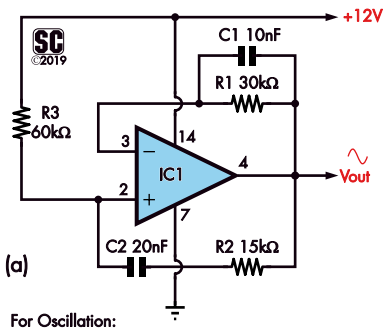
I found circuit (a) the most stable, both in terms of frequency and amplitude. The amplitude can be adjusted by varying the value of the bias resistor, R3 in each circuit.

I observed some clipping on top of the sinewave from circuit (b). This could be eliminated by fine-tuning the value of R3. Once tuned, the circuit is stable.

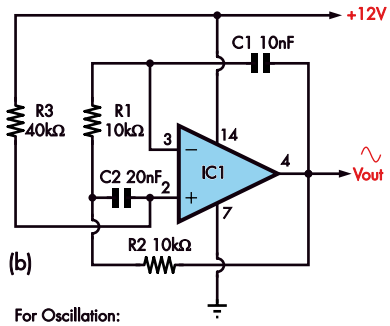
This circuit has the advantage that R1 and R2 can be equal in value, which might allow frequency tuning using a dual-gang potentiometer. But DC biasing would require some thought in this case.

Circuit (c) is more sensitive to component values than the other two. A good sinewave output can be obtained by adjusting the value of either R1 or R2. The frequency determining capacitors C1 and C2 are equal in value, which might allow tuning of frequency by using a dual-gang variable capacitor.

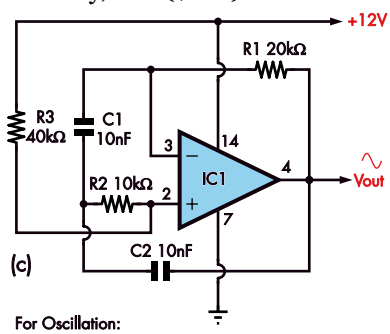
Mauri Lampi,
Glenroy, Vic. ($100)



For Oscillation:
R2/R1 + C1/C2 = 1
Calculated Frequency: 530.5Hz
Measured Frequency: 556.6Hz
IC1 = ¼ of LM3900, MC3401 or CA3401



For Oscillation:
C2/C1 – R2/R1 = 1
Calculated Frequency: 1125.4Hz
Measured Frequency: 1133.9Hz
IC1 = ¼ of LM3900, MC3401 or CA3401



For Oscillation:
R1/R2 – C2/C1 = 1
Calculated Frequency: 1193.6Hz
Measured Frequency: 1171.09Hz
IC1 = ¼ of LM3900, MC3401 or CA3401

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We will pay good money to feature it in Circuit Notebook. We can pay you by electronic funds transfer, cheque or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP Online Store, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

Amplifying audio signals using a MAX232CPE

This circuit employs the popular MAX232CPE serial driver chip, but in a completely different application than the device was conceived for. Despite that, it achieves reasonably good performance.

The circuit is an analog audio preamplifier which can produce a symmetric output swing of around ±8V (ie, 16V total) despite running from a 5V DC supply. It can provide a small signal gain of up to about 400 times.

It could have many different applications, as a general purpose preamplifier to feed a small amplifier chip, or perhaps to polarise varicap diodes in an FM modulator.

In that application, its wide output voltage range would allow a higher variation of the varactors' capacitance and thus a greater modulation depth than would be possible with a rail-to-rail op amp in the same role, running off 5V.

It works as follows. The audio signal is coupled to input pin 10 of IC1 via a 47µF electrolytic capacitor and a 1kΩ current-limiting resistor. The signal is DC biased to a couple of volts above ground by a divider across the 5V rail. This comprises 25kΩ trimpot VR1, an 18kΩ resistor and a 15kΩ resistor.

Diodes D1 and D2 prevent input pin 10 from being driven above +5.6V or below -0.6V in case a large amplitude signal is applied.

Due to the absence of the typical hysteresis and by employing a 1MΩ feedback resistor and the aforementioned bias-setting resistors, which also form a voltage divider with this feedback resistor, the inverter is kept in the linear zone. This allows analog amplification to occur.

VR1 is adjusted for maximum symmetric output excursion, so that the maximum amplitude is obtained at the output before saturation. The signal at the output of the inverter (pin 7 of IC1) provides an amplified signal which swings between approximately ±8V.

The circuit shows an extra 10µF coupling capacitor and 56kΩ biasing resistor which converts this signal to one which swings between 0V and +16V, by DC biasing the output using the +8V available at pin 2 of IC1.

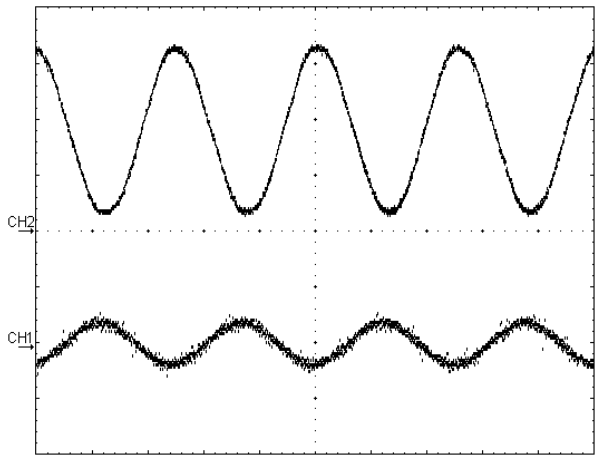
However, you could omit those components and take the output straight from pin 7 if you need a signal which swings both above and below ground.

Note that only one of the four amplifiers in IC1 is being used. There is a second amplifier which could be configured similarly if you need to pass a stereo signal, or want more amplification stages, connected to pins 11 & 14. The other two amplifiers work differently and will not produce the same output signal swing.

I tested this circuit with three different MAX232 variants. The first was an old one manufactured by Intersil (ICL232CPE, date code H0014BQPN) which worked fine, as did a more recent example from Maxim (MAX232CPE, date code +1715). However, a different version of the IC, MAX232N made by Texas Instruments, does not work in this application.

The capacitors connected to pins 1-6 are of the values recommended by the manufacturer and should have a minimum rating of 25V DC.

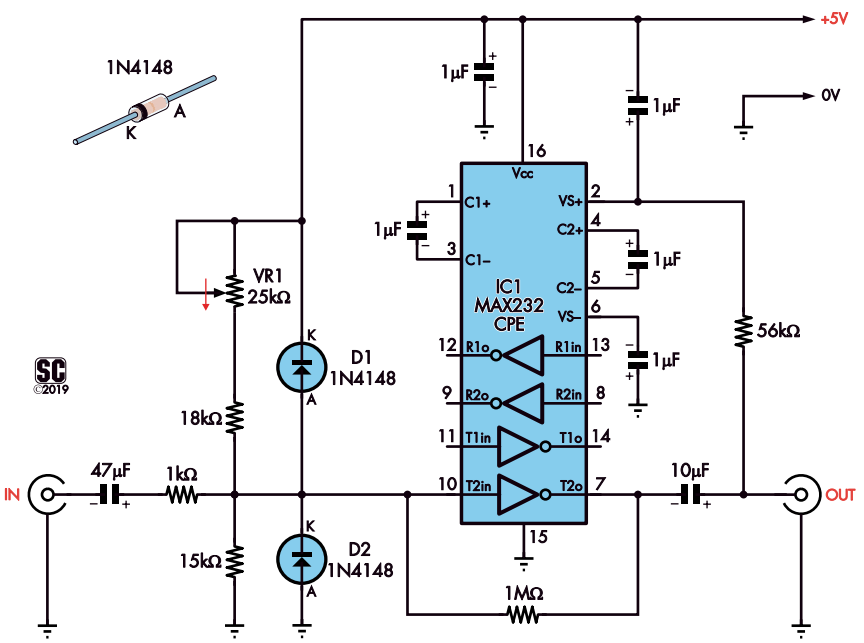
IC1 uses these capacitors to convert the 5V DC supply to approximately ±8V DC, usually used to produce RS232 signals with a symmetric swing, although in this circuit, these rails instead power the inverter stage as a linear amplifier.



The accompanying scope grab shows a 4kHz signal of around 36mV peak-to-peak being fed into the circuit at the bottom, and the resulting 14.5V peak-to-peak output signal at the top. Note that the scales used are very different; 50mV/div for the bottom trace and 5V/div for the top trace.

You can see that there is a little distortion on the output sinewave, but it is still clearly sinusoidal. The -3dB upper cutoff frequency is about 18kHz, and the lower cutoff frequency is under 10Hz. These values are adequate for amplification of human voice and a wide range of other audio signals.

Ariel G. Benvenuto,
Paraná, Argentina ($75).



Multiple DS18B20 temperature sensors on a single, long wire

I work as an engineer at a coal power plant, and as you would expect, there are lots of things that need to be constantly monitored.

Each 500MW steam turbine requires 1550 tons/hour of steam flow, which after expansion in the gigantic steam turbine, goes back to the condenser to be cooled down to form water again. Cooling such massive quantity of steam at high ambient temperatures back to water at 50°C requires about 540kcal/kg of heat to be removed.

To achieve that, about 60,000 tons of water is circulated through the steam turbine each hour continuously. This water is cooled down to ambient by a massive cooling tower.

The cooling tower of a typical 500MW boiler unit has ten huge individual cells in which hot circulating water from the steam turbine is poured from the top and air is blown from the bottom, so that the water bubbles, and the air takes away as much heat as possible. We were finding that some of these cells in some towers were not working correctly, impacting the overall water cooling performance.

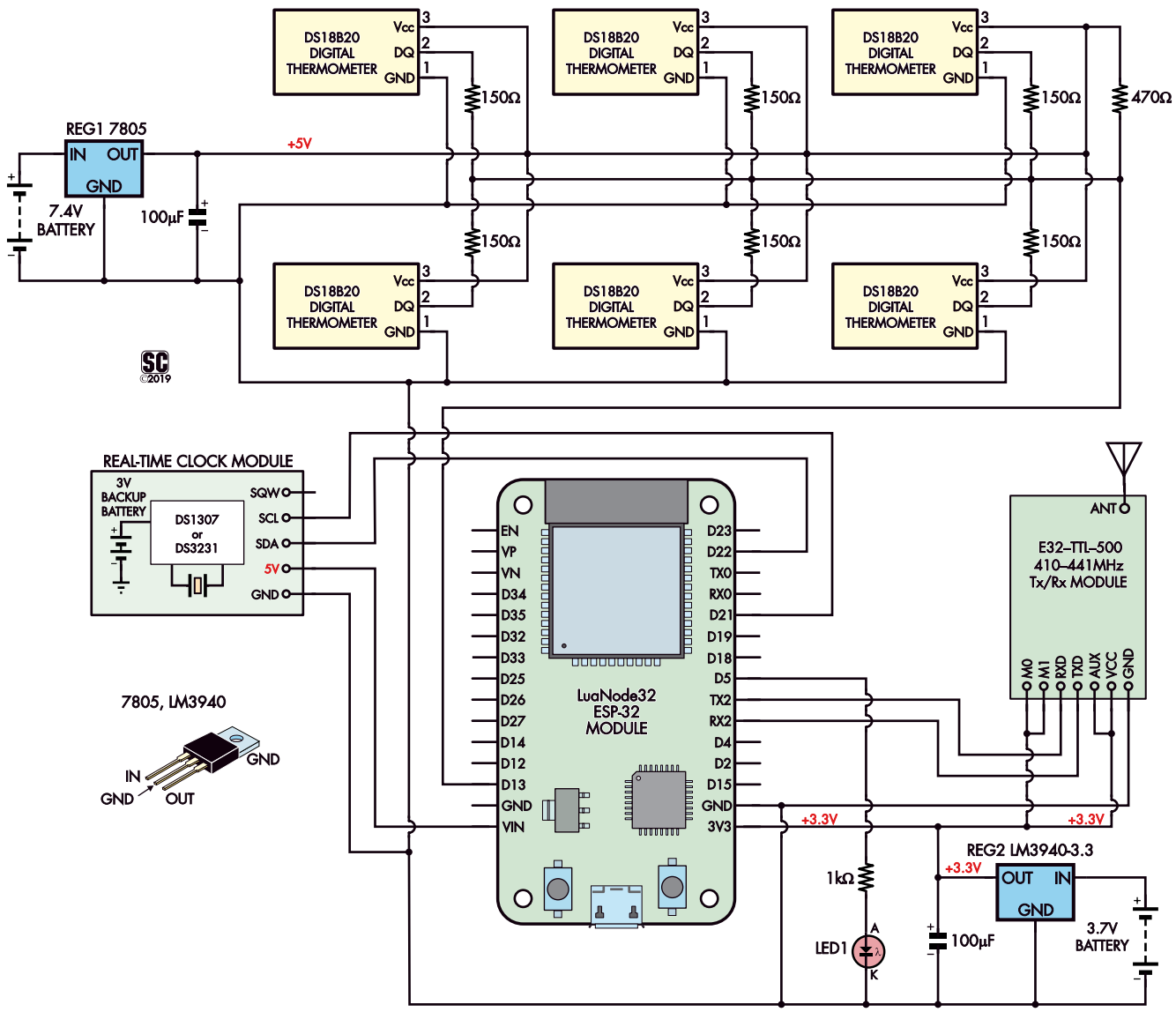
So we need to monitor the temperature at dozens of locations, starting with each cooling cell in each cooling tower. We also need to monitor the temperature at many points along the pulverised fuel pipe, to ensure the fuel cannot burn prematurely, and also at various points along a coal-carrying conveyor belt.

To do all this, I planned to use many DS18B20 digital temperature sensors arranged along wires that could each be hundreds of metres long. So I had to do some experiments to see how many sensors I could connect to a single wire, how long that wire could be, and what type of wire works best.

One of the great aspects of the DS18B20, besides needing just a single wire for communications and either two or three wires total including power (depending on how you power them), is that each one has a unique identifier.

So in theory, you can connect as many of these sensors as you want on a single bus and communicate with each by its ID.

I connected 20 DS18B20 sensors along a 470m-long cable and found that I could read the temperature from each sensor just fine. Good quality cable is required, though. My initial test



with single-phase (three-wire) power cable was successful, but I later tried using 1mm^2 copper solenoid cable and it did not work well at all.

My conclusion is that the best cable to use is 3-core 6mm^2 aluminium power cable or 3-core 2.5mm^2 copper cable, which is suitable for this application with lengths of up to 500m.

The circuit shown is the one that I have now deployed in the plant. It shows six sensors connected to the bus, but I am using many more than that.

They are all connected in the same manner. The 150Ω resistors isolate each sensor from the cable capacitance while the unusually low 470Ω pull-up resistor is required due to the large distributed capacitance (the recommended value is 4.7kΩ).

As the cable has three cores, the sensors are used in 3-wire mode, with a separate 5V power supply provided by REG1 from a two-cell Li-ion battery. A mains power supply could also be used.

The sensor grounds also connect back to the ESP32 module, along with the signal line, which goes to digital input D13.

The ESP32 board is programmed using the Arduino IDE and is configured with a real-time clock module, connected to its I^{2}C serial data pins, and a 433MHz LoRa transceiver, connected to its second serial port (TX2/RX2).

Software running on the ESP32 reads the temperature from each sensor in turn and relays the results back to a PC, with an identical LoRa transceiver connected via a USB/Serial adaptor.

The ESP32 relay module is powered from a single Li-ion cell, regulated to 3.3V by LDO regulator REG2. LED1 is driven from the ESP32's D5 digital output, via a 1kΩ current-limiting resistor, and flashes to indicate that it is active.

The software is named "multiple_ds18b20_by_address.ino" and can be downloaded from the Silicon Chip website. It is quite simple; most of the work is done by the OneWire and DallasTemperature libraries.

When the ESP32 is powered up, it scans the 1-wire bus to determine the number of devices on it, then generates an array containing the unique ID of each one.

It then continuously runs through that array, acquiring the temperature from each device in turn and printing it to the serial port, where it is fed to the LoRa transceiver and onto the host PC.

You will need a way to figure out which sensor ID corresponds to each physical sensor to interpret the data; for example, you could heat each one in turn and see which temperature reading rises.

Note that you will need to have the ESP32 board file installed in your Arduino IDE to compile the sketch, and you will also need to ensure that the correct Board is selected (eg, "ESP32 Dev Module").

A second sketch is also provided in the download package, which demonstrates how the temperatures from eight sensors, identified by fixed ID strings, can be read and then fed to the PC as a single line in CSV format, along with the time and date from the real-time clock module.

Bera Somnath,
Vindhyanagar, India. ($75)

Loudspeaker thump suppressor

I recently built a 40W subwoofer amplifier based on an LM3876 chip. I immediately noticed that when the amplifier was powered on, it gave a loud thump, then at power off, I got a squealing sound from the loudspeaker.

I designed this circuit to stop both unwanted noises. There are a multitude of similar circuits on the web, and all Australian electronics magazines have published suitable designs with varying degrees of complexity. As I had minimal space, I required a simple circuit. This single-transistor suppresor is based on the circuit from the ETI-440 25W audio amplifier from July 1975.

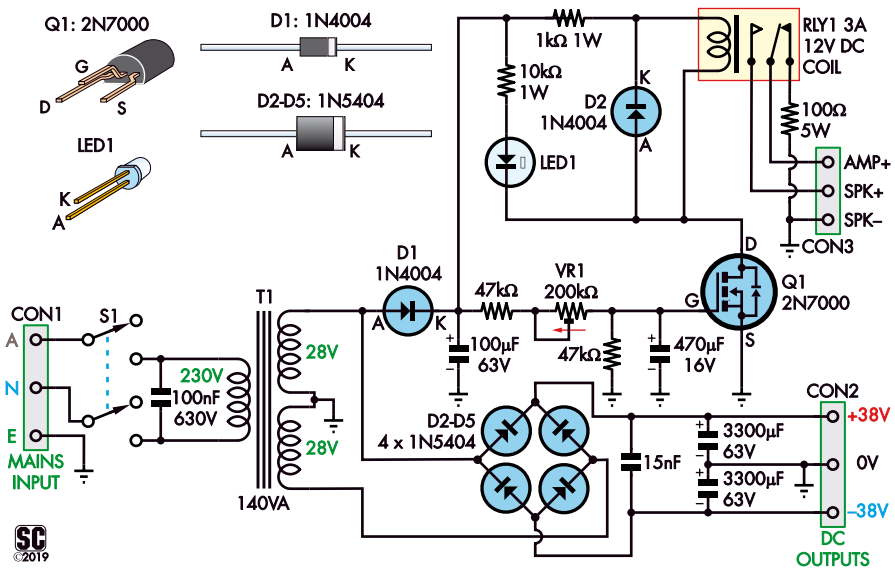
A relay is used to prevent the power on and off transients from reaching the speaker. A quantity of the AC voltage from the secondary of transformer T1 is half-wave rectified by diode D1 and applied to a voltage divider, supplying a small bias to the gate of Q1. This bias takes time to charge up the 470µF capacitor and when it reaches a voltage threshold, Q1 switches on, powering the relay.

This delay gives the amplifier time to settle before the speaker is connected to its output. When power is switched off, the relay coil quickly discharges the 100µF capacitor, so after a slight delay (and before the amplifier can 'misbehave'), the loudspeaker is disconnected.

I included a dummy load resistor of 100Ω on the relay's normally-closed contacts so that the amplifier is loaded at all times, preventing any upsets when the relay is off.

As Mosfet Q1 has high input impedance, multi-turn trimpot VR1 can be used to adjust the on-time delay between one and nine seconds. LED1 lights up to indicate when the speaker is connected. The remainder of the circuitry provides the split supply rails for the amplifier itself.

Andrew Kollosche,
Armidale, NSW. ($65)



ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Micromite LCD BackPack V3 questions

Thanks for the Micromite BackPack V3 (August 2019; siliconchip.com.au/Article/11764). I have a RevC PCB, and I have been trying to work out how CON8 (for I²C) is configured.

On page 34, you state that the pinout of CON8 matches the commonly available BMP180/BMP280 and BME280 sensor modules, and that these can be soldered in directly. I checked the BMP180 I purchased from Silicon Chip. The CON8 pinout matches the 4-pin header on my BMP180 module, but the module shows a 5V supply input, while the Micromite PCB delivers 3.3V. I think CON8 should have 5V on it.

And what is the difference between the IRLML2244 Mosfet specified for Q2, compared to the DMP2215L used in the V2 BackPack? Did this need to change because of the new display? (R. S., Epping, Vic)

● The 5V supply pin on the BMP180 modules is connected to the input of a 3.3V low-dropout regulator on the PCB. So if connected to the V3 BackPack board, the 3.3V supply will be closer to 3.1V (the regulator has a dropout of around 0.2V). This will not cause any problems as the BMP180 will work down to 1.8V.

See our article in the December 2017 issue of Silicon Chip on BMP180 modules for more details on that sensor (siliconchip.com.au/Article/10909).

We changed from the DMP2215L Mosfet to the IRLML2244 only because the former is now obsolete and becoming difficult to get. They are interchangeable in this application; you could use an IRLML2244 on a V2 BackPack or a DMP2215L on the V3 BackPack, if you can get one.

Using BackPack V3 for earlier projects

I am a long-time reader of Silicon Chip magazine and its predecessors and have built several of your analog-based projects. However, I have now been tempted into the digital realm by reader Dan Amos' Touchscreen Clock Radio design (Circuit Notebook, June 2019; siliconchip.com.au/Article/11676).

Can I build this design with the Micromite LCD BackPack V3 (with a bigger touchscreen) in place of the V2 BackPack specified for that design, with the same software?

I have already ordered the FM tuner, amplifier, clock and regulator modules from your Online Shop. I like the possibility of additional features like remote control. I would appreciate your advice on this one before I order the BackPack kit. It sounds like a cool little project. (O. G., Tauranga, New Zealand)

● We see no reason why the V3 BackPack with ILI9488 display could not be made to work for the Touchscreen Clock Radio, but the screen graphics sizes and locations are hard-coded into the BASIC software. So you would have to go through the program code and manually change all the graphics coordinates to make full use of the larger screen size.

Otherwise, the graphics will be displayed in the top-left corner of the larger panel, and given that the larger display has a higher resolution, the displayed graphics will be considerably smaller.

You will also need to add the ILI9488 display initialisation routines to the start of the Touchscreen Clock Radio program. So the short answer is yes, you can do it, as long as you're happy to tinker with the BASIC code. We haven't actually tried it ourselves.

RF Signal Generator leakage tests

I'm interested in building the RF Signal Generator (June-July 2019; siliconchip.com.au/Series/336). I have spotted what seems to be a problem in the case top cover drawing. There is no width shown. Does it have to be deduced from the bottom cover?

There also seems to be an error in the PCB pattern PDF download. The only tracks visible are for the attenuator section.

Finally, did you do any leakage tests? If the leakage is low enough, an additional output attenuator would be a useful accessory for testing sensitivity or alignment of receivers etc. (G. P., Narre Warren, Vic)

● Sorry, the case top cover width (157mm) was accidentally left off the top cover cutting diagram. A revised diagram with the missing dimension added has now been uploaded to our website.

Some PDF viewers have trouble displaying multi-layer files. The PCB pattern file originally uploaded contained some rasterised elements (not ideal for etching a PCB). So we have replaced it with a fully vector-based file. That will probably also fix your track problem.

No, we have not measured the leakage of the generator. We do not have adequate facilities to make that measurement with any degree of confidence.

The PCB layout is not ideal for low leakage. Ordinarily, that requires the PCB to have a better-designed power supply, plus integrated ground stitching around carefully delineated sections for the attenuators, buffer amplifier, filters and the DDS board. Such a PCB could then be used with a suitably designed milled aluminium chassis with RF gasketed top and bottom covers to give much-improved leakage performance.

During development, Andrew did consider taking such measures. He considered using a graphite-impregnated 3D printed enclosure, or conductive plating of a more conventionally printed PLA 3D enclosure. Sadly, basic tests of these approaches did not produce good results.

You need lots of metallic plating and really thick walls to achieve good shielding, and the graphite filament was very hard to use and insufficiently conductive to give good shielding.

As HP/Agilent/Keysight and similar products clearly demonstrate, you need solid chunks of cast aluminium to do a good job.

Consider that the overall design was aimed at delivering a basic feature set, at a modest cost and with ease of construction. The sort of shielding required to minimise leakage complicates construction considerably, and drives up the cost dramatically.

The lowest-hanging fruit in terms of reducing leakage would be improved power supply filtering. Coupled with that would be the use of relay-driven attenuators, since the slide switches are a major source of leakage and cannot easily be shielded. A revised board and milled chassis could then be developed together to produce a suitable result. But we don't have any plans to do that.

We suggest that it would be much easier to build the Signal Generator as designed, then set it up for a test and carefully place it in a diecast aluminium box along with a Li-ion battery for power. You can even build a PCB specifically for this type of test, with the PCB attenuators permanently in-circuit and no variable pot attenuator fitted.

The output can then be fed through a panel-mounted SMA female-female coaxial adaptor mounted on the diecast box. With high-quality external attenuators, this approach allows you to reach -120dBm output levels reliably. It is a bit fiddly when it comes to adjusting frequencies or modulation, but generally, those tend to be set to one value for a particular measurement.

This approach is simple and reasonably practical, if time-consuming.

Using Battery Isolator with $LiFePO_4$ battery

Liked the project article on the 12V Dual Battery Isolator (July 2019; siliconchip.com.au/Article/11699); it could be what I'm looking for!

I am an amateur radio enthusiast, and I like to have a VHF/UHF transceiver in the car. With my last car, a Honda CR-V, I had a simple arrangement with a direct connection from the rather large starting battery to the transceiver. I had a short time-off setting on the transceiver to save the battery in case I forgot to switch it off.

However, having 'downsized' from my 12-year-old Honda CR-V to a Nissan Note, I have run into some problems. Due to its compact size, I intend to have the transceiver's main body in the boot and a remote head in the cab.

My original idea was to also have a small battery ($LiFePO_4$ or similar) in the boot by the transceiver, with a high-current set of wires to the battery in the engine bay via some sort of split-charge/isolation arrangement. But this car has automatic engine stop/start with an 'intelligent' alternator and probably a load sensor on the battery negative to chassis.

I'm concerned that this will not play well with the transceiver, as it may not keep the battery fully charged all the time.

So, as all non-hybrid or EV vehicles seem to be going this way, do you know if this project would suit a modern vehicle with this sort of charging system? There must be lots of us "hams" in this situation these days! In any case, many thanks for your help – and keep up the rather excellent magazine! (R. P., Bromley, Kent, UK)

● Bruce Boardman responds: I am not familiar with the Nissan Note specifically; however, many modern vehicles now have intelligent charging systems which I think are more designed to meet the 'eco' requirements than to actually charge the battery.

Having said that, to charge a lead-acid starting battery requires around 14.2V, and when the current falls, around 13.8V or sometimes a bit less. An auto/eco stop-start vehicle (providing it has a 12V system) would still need to charge its lead-acid battery adequately. So the battery isolator will still connect the second battery in the boot for charging when the main battery voltage is high enough.

My experience with $LiFePO_4$ batteries is that they are packaged with protection circuitry to protect against over-current, over-charge and over-discharge, so the battery isolator would probably charge them OK.

However, note that if the isolator is switched on when the engine is started, it would be possible to pull significant current from the second battery. This would only be for a very short time, as the starting voltage would be less than 12.6V and the isolator would quickly switch off.

I recommend that you spend a little time monitoring your vehicle battery voltage while driving (but only when it's safe to do so; don't get distracted!). This should give you an idea of how the charging is managed and the range of typical voltages.

Ideally, the battery isolator should be used with batteries of the same chemistry, as they will be charged in parallel. But I think that it will manage OK with a primary lead-acid battery and a secondary $LiFePO_4$ battery, as long as the latter is stated as being compatible with lead-acid chargers.

Regarding your concern about a load sensor on the battery negative terminal, you could simply run a single positive conductor to the boot and the negative could go to the vehicle chassis. The load from the main battery would then be sensed the same as any other load and not cause a problem.

Programming PIC32s with PICkit 2

I recently downloaded the HEX file for the Bad Vibes Infrasound Snooper from June 2015 (siliconchip.com.au/Article/8600) off your website. This is for a PIC32MX170F256B chip. Can I program this using a PICkit 2 programmer rather than the PICkit 3 or PICkit 4? (P. D., Canterbury, UK)

● You can see a list of PIC chips that can be programmed by the PICkit 2 at: siliconchip.com.au/link/aaux

There are very few PIC32s on that list, and it doesn't include the PIC32MX170 series. So you need a newer PICkit to program that chip.

DSP Active Crossover with digital audio

Can you tell me whether the DSP Active Crossover / Parametric Equaliser (May-July 2019; siliconchip.com.au/Series/335) can be made with a digital audio input board, rather than converting analog audio to digital data using the CS8416 stereo ADC? Turning a digital audio signal to analog, only to convert it back to digital is a waste and affects sound quality.

I'd also like to see a version of this project to suit three-way systems. (D. R., Dargaville, New Zealand)

● Phil Prosser replies – the Active Crossover does not have an asynchronous sample rate converter (ASRC). So an S/PDIF or TOSLINK digital audio input signal would be at a different clock/sample rate compared to that used by the DSP chip.

To add an S/PDIF or TOSLINK input would require a separate digital input board with an ASRC.

But then the digital signal being processed would not be identical to the incoming signal. The only way to avoid an ASRC is to lock the DSP rate to the incoming clock rate, which has a big impact on flexibility (eg, you lose the ability to have multiple inputs) and that would require a redesign.

I have tested the distortion performance of the DACs and ADCs in this project and am really surprised by how good they are.

The dynamic range of the analog inputs and outputs is well above the 96dB dynamic range of which 16-bit digital audio sources like CDs are capable. So practically speaking, I don't think the extra work required would have much benefit, even though there is something reassuring about going all-digital.

I will look into the idea of a receiver/ASRC board that is compatible with the DSP Active Crossover and that can accept a master clock from the DSP. I don't believe that the PIC has the power to implement a proper ASRC in software.

Transformer rating for DSP Active Crossover

I'm building the DSP Active Crossover (siliconchip.com.au/Series/335). I've built the power supply board, and I want to feed it power from a 12V centre-trapped transformer. I'm not sure of the current requirements for the circuit and so unsure which transformer to buy. There are lots available but I don't want to go overboard.

Can you tell me the necessary current capacity, please? (J. L., Rossland, BC, Canada)

● Total current draw from the transformer is less than 400mA, so a transformer around 10-12VA should be easily sufficient, for example, 12V 1A or 24V centre-tapped (12-0-12), 500mA per winding.

433MHz Range Extender inductor queries

In the 433MHz Range Extender article on page 51 (May 2019; siliconchip.com.au/Article/11615), it states that inductor L1 is 17 turns of 1mm enamelled copper wire wound on a 25mm diameter toroidal core.

When I wind 17 turns of 1mm copper wire on a Jaycar LO1234 (25 x 15 x 10mm) pot core and test it using my LC Meter, I get an inductance of around 260µH, not the 47µH noted in the circuit diagram on page 51, or in the TL499A data sheet.

The other option I have come up with is to fit a pre-wound Jaycar LF1274 choke (~21.5 x 12 x 12mm) which has a nominated value of 47µH and tests at 47-50µH. It also fits the PCB much better than the larger LO1234 core.

I also note that the pot core mentioned in the parts list on page 49 is the smaller Jaycar LO1242 (15 x 8 x 6.5mm). This core fits the supplied PCB quite nicely, but when wound with 17 turns of 1mm wire, the inductance is only 15.7µH (23µH with 0.8mm wire). Is the lower 15-23µH inductance on this smaller core sufficient to run this project or would the pre-wound 47µH option be better?

Thanks for the interesting articles and projects. (W. G., Dunedin, New Zealand)

● The powdered iron core we used was the LO1242, as mentioned in the parts list. Its dimensions are 15 x 8 x 6.5mm. The 25 x 15 x 10mm dimensions mentioned in the parts list and text are incorrect.

The number of windings we specified provided the best results for reliable starting and achieving the desired output voltage from the TL499A switchmode converter.

So we recommend that you stick with 17 turns of 1mm wire on the Jaycar LO1242 core, rather than using a prewound inductor.

Lithium batteries for boats and caravans

I was at a caravan and camping show, and there was a vendor with a whole lot of stuff that included some 12V wonder batteries based on "lithium technology" that you were supposed to be able to connect directly to your 12V vehicle electrical system – no special charge controller needed. And they were on special for only $999!

That probably upset the bloke in the stand three doors down that was selling an equally expensive caravan battery charger.

It stepped up the vehicle voltage and then controlled it so that the remote battery got its full charge, regardless of the charge state of the vehicle's starting battery.

Being slightly suspicious and knowing that lithium batteries have totally different charging requirements to a lead-acid automotive battery, I had the feeling that this gentleman was selling the 21st-century version of "snake oil".

Was I wrong? Is there really a lithium battery that can be installed in a boat or caravan and will charge successfully and reliably from the same source as a conventional lead-acid battery? (D. H., Beechwood, NSW)

● Those are almost certainly $LiFePO_4$ rechargeable batteries. We had an article on that technology in June 2013 (siliconchip.com.au/Article/3816) and subsequently used 12V batteries based on the technology in our 800W+ Intelligent UPS project (May-July 2018; siliconchip.com.au/Series/323).

Have you seen Jaycar's range of $LiFePO_4$ batteries? They have recently expanded it quite significantly. You can see their range at: http://siliconchip.com.au/link/aauu

You can treat them like regular lead-acid batteries, although they're best used in deep-discharge type applications rather than standby applications where they're left on float charge for long periods.

They will handle many deep discharge cycles (more than just about any lead-acid battery), but there's a question over whether they last as long as AGM batteries if kept fully charged for long periods.

$LiFePO_4$ cells will charge quite happily at 3.6V, so it's a useful coincidence that four such cells in series require a charging voltage of 14.4V (3.6V × 4), which is pretty much exactly the standard charging voltage for a lead-acid battery at 25°C.

If your charger has temperature compensation, it's best to disable it for $LiFePO_4$ batteries, as their charging voltage does not change with temperature like lead-acid.

Note that you may still need a 'booster' circuit to charge a $LiFePO_4$ auxiliary battery, depending on the distance from the vehicle battery/alternator and other factors. But the $LiFePO_4$ batteries cannot usually be charged as fast as a large lead-acid battery, so the voltage drop in the cabling is generally less of a problem.

Continued page 110

VINTAGE RADIO

By Ian Batty

Healing M602T transistor mantel radio

Good performance and long battery life with ‘modern’ 60s styling – a transistor radio that’s at home in the kitchen.

I picked up this transistor set at an HRSA auction a while ago. It’s an Australian set, compact and easy to use.

I recently described Healing’s fine valve portable, the 404B (April 2019; siliconchip.com.au/Article/11533). So we can now directly compare that to the six-transistor M602T from the same manufacturer.

The M602T was released in 1960 and followed on from the designs that had matured by the late 1950s. It uses six alloyed-junction transistors: three in the RF/IF section and three in the audio stages. This puts it in the second generation of transistor sets. The short-lived first generation used inferior grown-junction transistors.

So as well as comparing this set to the valve radios that were designed just a few years before it, we can also compare it to the transistor sets which came soon after (ignoring the few hybrids which bridged the gap).

The M602T’s construction uses a design that was passing out of favour at the time: a punched and pressed steel chassis using tag strips, transistors mounted in grommets, and point-to-point wiring. Its mechanical construction is complicated, with three metal sub-chassis sections.

The plastic cabinet is quite generous, putting it in the ‘small mantel/portable’ class. The chassis, although not especially compact, leaves plenty of room for its 5-inch Rola 5F speaker and the long-lasting type 276 battery.

It’s a conventional six-transistor set, using the same cabinet as mains-powered valve models 410E & 411E.

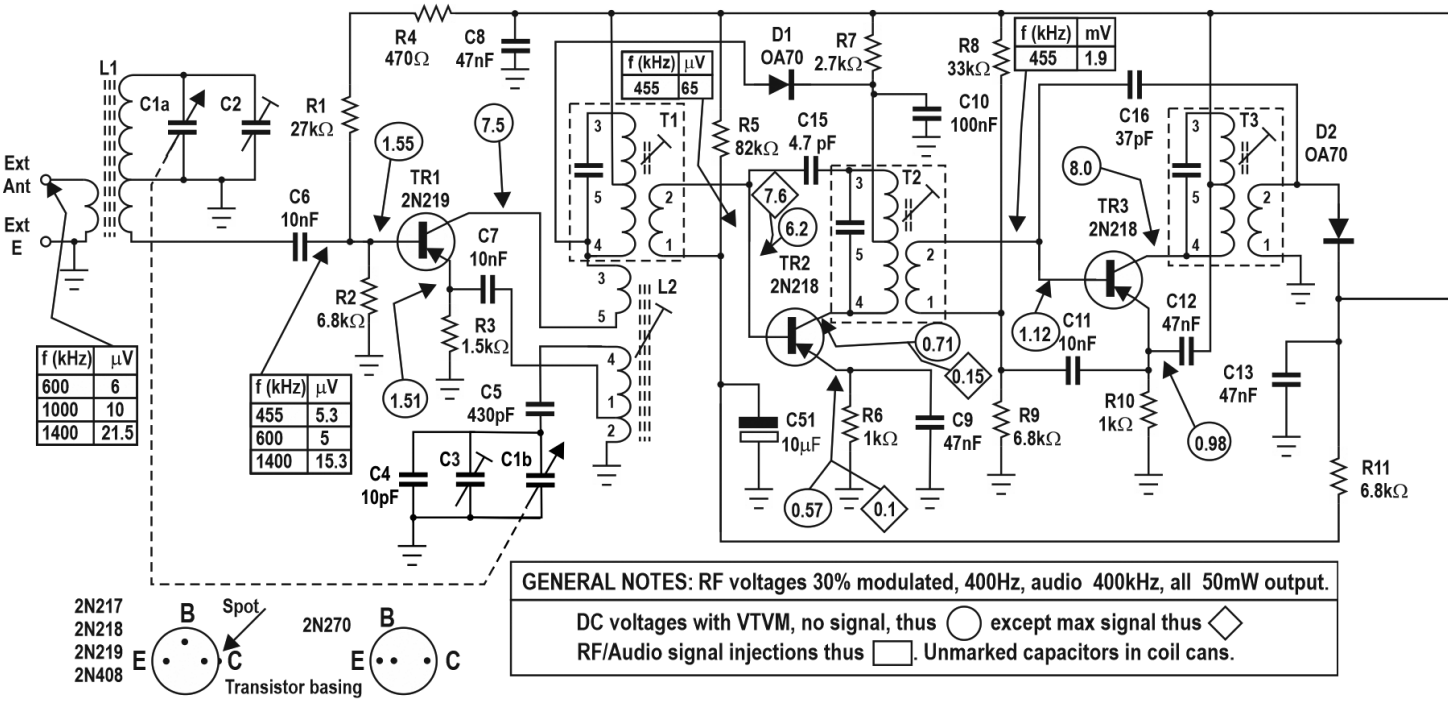
Being a larger set than the 404B, the M602T has a more relaxed and usable control layout. The large dial features station call signs, a reminder of Saturday afternoon footy and Top Forty Hit Parades. The slow-motion dial makes tuning easy.

From top to bottom, the knobs are the on/off switch, volume control and tone control. Separating the on/off and volume functions reduces wear and extends the life of the volume pot, as it can be left in the same position most of the time. I wish the controls were labelled; maybe you’re just meant to know.

Compared to the all-valve 404B, the M602T is a pleasure to work on, though its complicated construction sees the tuning gang buried between the front and back chassis plates, and the trimmer capacitors partly obscured, so adjusting it is a bit difficult.

As the IF transformers are all single-tuned, the slugs are easily accessible from the rear.

On my set, they appeared to use wax to prevent accidental movement, so I strongly advise against using metal-tipped alignment tools. If you need



to get a slug to move, try using a hair dryer/heat gun to warm the can and soften the wax.

All minor components, including the transistors, are easily accessible for measurements or replacement.

Circuit details

The circuit of the M602T is shown above. Note that some sets may have alternative transistor types to those shown, especially the ones which were made in Japan.

The circuit begins with the usual self-oscillating converter, TR1. This is a 2N219 or a 2SA15, roughly equivalent to an OC45 rather than the higher-performing OC44 or similar that we're used to seeing in this stage. The converter uses emitter injection, so it's easy to inject a signal directly into the base for testing.

The antenna circuit has a ferrite rod with a separate primary winding to allow an external antenna connection to be used.

As is usual for converters, the base-emitter forward bias of some 50mV is lower than the usual 150~200mV for germanium transistors. This is because converters need to operate in a non-linear mode close to Class-B, so that they can create the necessary sum-and-difference signals from the incoming radio station and the local oscillator (LO).

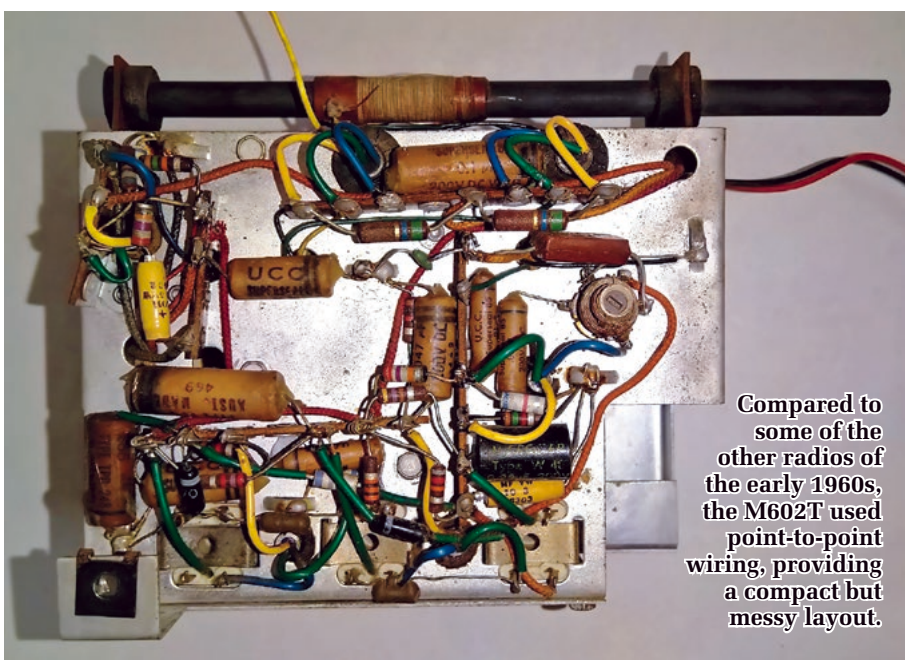
LO transformer L2 has two windings, with the secondary tapped to supply feedback to the low-impedance emitter.

As the tuning gang has identical sections, padder C5 (430pF) reduces the LO section's capacitance swing to give a ratio of roughly 4:1 as the set tunes over the broadcast band.

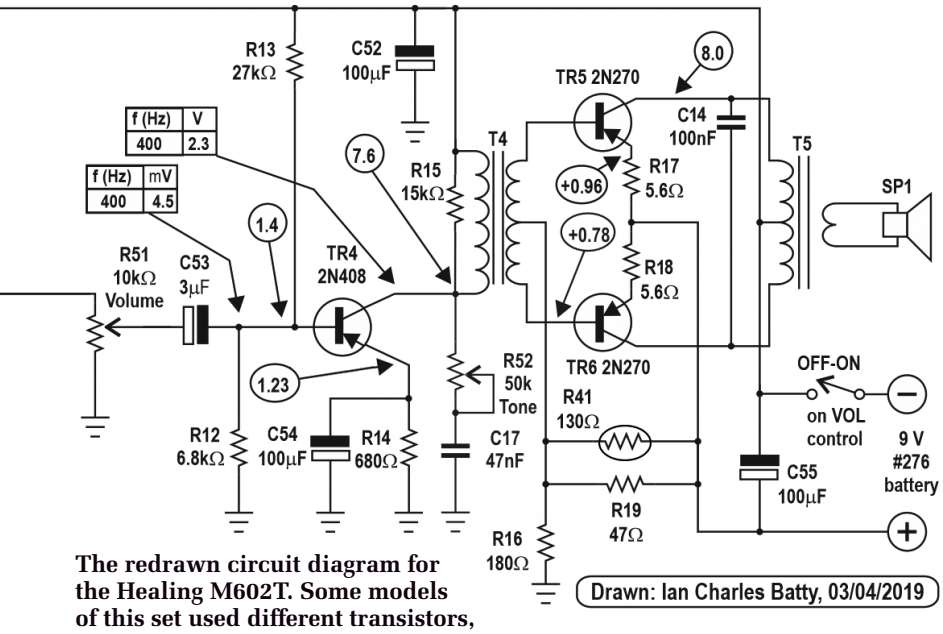
The converter feeds first intermediate frequency (IF) transformer T1. This has a tapped, tuned primary and untapped, untuned secondary.

The first IF amplifier transistor, TR2, is either a 2N218 or a 2SA12, both slightly lower-performing versions of the 2N219/2SA15. As the stage is gain-controlled, bias resistor R5 has a relatively high value of 82kΩ. This allows the AGC signal from diode D2 to reduce TR2's gain with increasing signal strength. This is filtered by 6.8kΩ resistor R11 and 10µF capacitor C51 to remove the audio component.

TR2 feeds second IF transformer T2, also with a tapped, tuned primary and untapped, untuned secondary. The collector is fed from the supply via a 2.7kΩ resistor, R7. AGC extension diode D1 has its cathode connected to R7 and its anode to the primary of first IF transformer T1.



Compared to some of the other radios of the early 1960s, the M602T used point-to-point wiring, providing a compact but messy layout.



The redrawn circuit diagram for the Healing M602T. Some models of this set used different transistors, most of them made by Hitachi, for the Japanese market. Additionally, the values of C8 (330nF), C11 (47nF) & C16 (56pF) differ, likely for similar reasons.

In normal operation, there's a voltage drop of about 1.8V across R7. Since the converter's collector sits at about 7.5V, D1 will have a reverse-bias of around 1.3V. This means that D1 is cut off with weak signals so it will have no effect.

As the AGC takes over, and TR2's collector current falls, TR2's DC collector voltage rises. This brings D1's cathode voltage closer to 7.5V, so D1 will start to conduct with strong signals. As it does so, it shunts current from the converter's collector, further reducing the set's gain and giving improved AGC action.

The 2N216~219 series are all alloyed-junction RF transistors, exhibiting collector-base capacitances of around 9pF. So both IF amplifiers need neutralisation, with 4.7pF capacitor C15 providing this for TR2.

Second IF amplifier TR3 uses another 2N218/2SA12 with fixed bias. The usual emitter bypass capacitor to ground seems to be missing, but this stage has its base bypassed back to the emitter terminal via 10nF capacitor C11, and its collector supply is bypassed to the emitter via 47nF capacitor C12.

This configuration is most often used in VHF circuits, as it is more effective than running everything to ground. In this circuit, it also saves one capacitor – the emitter bypass capacitor, such as C9 used by the first IF amplifier TR2.

TR3 feeds third IF transformer T3's tuned, tapped primary, and T3's untuned, untapped secondary feeds demodulator diode D2, another GEX34/OA70. D2's audio output, filtered by C13, goes to volume pot R51 and also provides the AGC signal, as described earlier.

Note that the AGC filter capacitor, C51, is an electrolytic type. Electrolytics are not recommended for RF/IF bypassing, so if you have an M602T suffering from oscillation or some other strange RF/IF fault, C51 may be the culprit.

The signal from the volume control is coupled to the base of audio driver TR4, a 2N408. TR4 has conventional combination bias, and its collector drives the primary of output transformer T4. The tone control pot, R52, and 47nF top cut capacitor C17 connect between TR4's collector and ground.

As R52's resistance is reduced, C17 progressively shunts more of the high audio frequencies, giving more and more top-cut and producing a more 'mellow' audio tone.

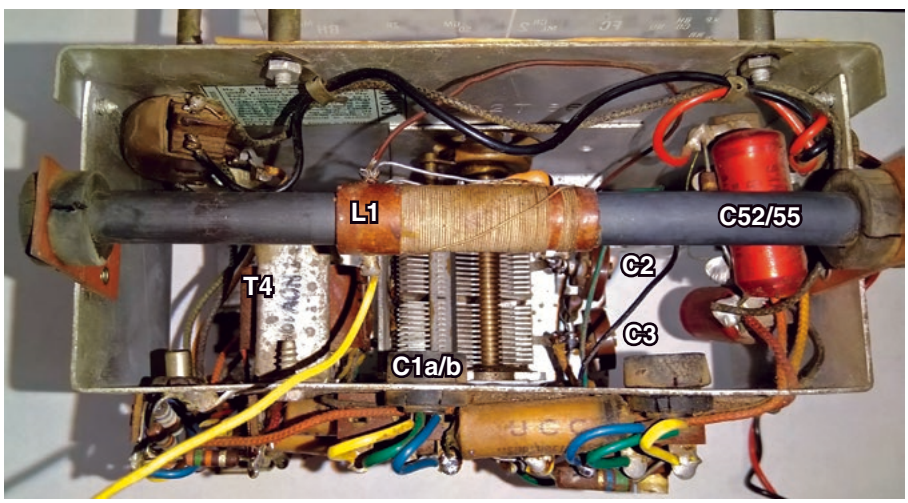
T4's secondary provides the push-pull drive to transistors TR5/6, both 2N270s. These have higher power ratings than the OC72, but less than the later OC74/AC128 types from Philips/Mullard. TR5/6 operate in Class-B, with around 180mV of forward bias.

Don't be confused by the positive voltage readings in the emitter/base sections of the circuit; I've measured relative to chassis ground, and since R16 is connected between the battery and chassis, the chassis sits about one volt below the battery's positive terminal.

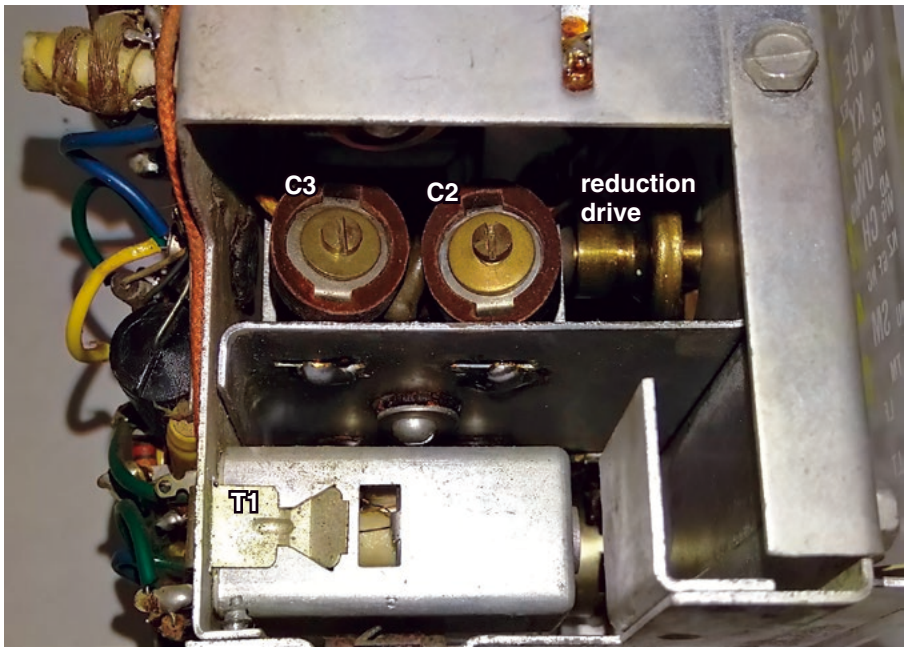
TR5/6 get their bias from the parallel combination of R19/R41 – again, a slightly confusing connection, but it works perfectly. Thermistor R41 compensates for ambient temperature, reducing the forward bias for TR5/6 at higher temperatures, where their base-emitter junction voltages fall. This provides a relatively constant collector current, protecting from thermal runaway.

Quirky decoupling

Class-B output stages draw low



From the top of the M602T, you can see two large red 100µF electrolytic capacitors, used for filtering the supply, at the far right. There are a few other electros in the circuit, which may cause oscillation problems if they degrade.



Variable trimmer capacitor C3, used to calibrate the oscillator, is shown at centre left. To its right is trimmer capacitor C2 for the antenna. Again to the right of C2 is the planetary reduction drive for the dial.

quiescent (idling) currents – it's the main reason for using them, despite their complexity compared to Class-A stages. But Class-B operation results in considerably larger swings in supply current, increasing substantially on output peaks.

These current peaks can impress the output signal on the supply voltage, making the entire set prone to audio feedback as the output signal finds its way back to driving stages. The simple remedy is to use decoupling, often just a simple resistor-capacitor filter, in the supply line going to the low-level RF/IF/audio section.

But the M602T applies the full battery negative supply to all stages. The decoupling circuit is placed in the positive supply, which in this case, is ground. It's odd but effective: output transistors TR5/6 do get the full battery supply, but the battery positive's connection to chassis and set Earth is via 180Ω resistor R16.

The battery itself (and thus the output stage) is bypassed by 100µF capacitor C55, and the driver/RF/IF stage supply is bypassed by 100µF capacitor C52.

The circuit office appears to have numbered ceramic and paper capacitors consecutively from C1, but started the electrolytics from C51.

The output stage's thermistor is renumbered as R41, and the volume pot as R51, despite there being about 20 fixed resistors in the circuit.

Cleaning up my set

The set I acquired was in fair cosmetic condition, the only damage being two melted areas on the top of the case and a missing "Transistor" badge on the decorative metal panel across the top of the front panel.

The tuning was very stiff. Inspection showed that the planetary reduction drive was stuck tight, so I removed, dismantled, cleaned and re-assembled it. It was then time to power up the radio, which still had all of its original components.

Perhaps unsurprisingly, it was dead. The culprit, an oxidised power switch, responded to contact cleaner and a good number of on-off-on-off cycles.

Having resurrected the set, it was time to check its alignment. It seemed to come up well in the IF department, and responded well at the low end of the broadcast band around 600kHz. But it got progressively more and more 'deaf' towards the top end.

I checked all the voltages but found nothing wrong. So I completely dismantled it and washed the 'dust of ages' from the tuning gang and the rest of the set with isopropyl alcohol. Once it dried, I checked it again, but still found it relatively poor at pulling in stations at the upper end of the frequency range.

Test results

Under my test conditions and for the standard 50mW output, the M602T needs around 175µV/m at 600kHz, 300µV/m at 1000kHz and 700µV/m at 1400kHz. Signal-to-noise ratios exceeded 20dB in each case. That's a significant drop-off in sensitivity. Signal injection figures recorded on the diagram also reflect this loss of sensitivity at the high end, and direct injections to the converter base confirm these figures.

This seemed unlikely to be a problem with the converter, a case of the mythical "tired transistor". Just to be sure, I replaced it with a new old stock (NOS) OC44, with no improvement.

You may know that conversion gain varies significantly with LO injection, so that there is a fairly narrow span of injection voltage for best performance. The LO voltage falls by more than 35% from 600kHz to 1400kHz, so perhaps this explains the weak top-end performance.

You may recall Kriesler's Mini 41-47 handheld radio (December 2013; **siliconchip.com.au/Article/5633**) using a germanium diode across the LO primary to help stabilise oscillator output. Perhaps that's what this set needs.

RF bandwidth is around ±1.6kHz at -3dB; at -60dB, it's ±33kHz. AGC action is excellent: a 40dB increase at the input gave an output rise of just 6dB. This set was excellent on strong signals, needing some 500mV/m before reaching overload.

Audio response is 150~4600Hz from volume control to speaker; from antenna to speaker it's 135~2000Hz. Fully on, the tone control slashes the upper -3dB point to just 450Hz.

This set can give 400mW of output at clipping, although that figure is a bit misleading. At 10mW, Total harmonic distortion (THD) is just 2.5%, but it's 7% at the test figure of 50mW, rising to the usual cutoff value of 10% at only 120mW output.

I suspect that mismatched output transistors are the reason for this, but my junk box failed to disclose any 2N270s. Rather than substitute, I'll leave this set all-original until I can get proper replacements.

At half the nominal battery voltage, the output clips at 120mW, which is still quite loud and enough to usefully squeeze those last few electrons from the battery.

The connections on the back of the set, next to the carry handle, are for an external antenna and ground.

Healing 404B vs M602T

The M602T weighs in at around 2.7kg, with the valve-based 404B a lightweight at just 1.95kg. The M602T is also a fair bit larger all around, giving a volume of 5700cm^3 versus 1470cm^3.

The M602T is about as sensitive as the 404B at the low end, but nowhere near as good at 1400kHz, needing some four times as much signal for the same audio quality.

The M602T's audio performance is superior, giving over four times the maximum output of the 404B, with a better frequency response due to a larger output transformer and speaker.

But I do like the 404B's visual design: it looks smart and perky with hints of Art Deco (despite being made roughly 20 years after that movement was popular). It stands out in a way that the more stolid M602T simply does not.

This all makes sense in context. The 404B was aimed at the burgeoning market of the late 1940s, with each manufacturer spruiking the newfound convenience of "camera case", all-miniature portables and hoping their attractive design would stand out from the pack. The M602T, with its external antenna and Earth connections, is clearly aimed at the more everyday "mantel market".

Which is the better radio? At moderate volumes, there's not a lot of difference. The M602T's transistor design, with its type 276 battery, gives over 100 hours of use, while the 404B's single filament supply cell runs out in less than five hours.

Given the 404B's total power consumption at over 900mW compared to the M602T's which is less than one-tenth of that, one of the transistor's principal advantages over the valve is confirmed: greatly reduced power consumption when doing much the same job.

And there's a clue in the M602T's rear cover. It's held in place with screws. That suggests that you're not expected to remove it very often to replace the battery.

Special handling

The four knobs (tuning, on/off, volume and tone) are push-fits. Mine were very hard to remove, so I used some dial cord looped about the shaft and re-looped to give four drawstrings. Be aware that the metal rims on the knobs are thin, and any attempt to lever under them will cause damage.

Output transistors TR5/6 are mounted in rubber grommets, effectively insulating them and providing even less heatsinking effect than wiring them onto tag strips and leaving the cases unobstructed, in free air.

If this set is delivering its full output of 400mW for any substantial time, that may cause significant heating of Q5/6, possibly leading to their destruction.

So if testing for maximum output with a continuous sinewave signal, be sure to keep the test brief.

You can find additional information on this set in the links below:

siliconchip.com.au/link/aau2
siliconchip.com.au/link/aau3
siliconchip.com.au/link/aau4 SC

A size comparison of the Healing M602T and previously described 404B.

Programmable Logic Controllers

Has Silicon Chip published any articles on programmable logic controllers (PLCs) in the last ten years or so? (M. W., New Zealand)

● We haven't published any articles on PLCs recently, but we suggest that you contact Ocean Controls by email (info@oceancontrols.com.au) or by phone (+61 3 9708 2390) as this is right up their alley.

You can view their online catalog of PLCs at: https://oceancontrols.com.au/Controllers.html

DAB+ Radio headphone noise problem

I have finished assembling your DAB+/FM/AM Radio (January-March 2019; siliconchip.com.au/Series/330). The articles make fascinating reading, particularly the January article explaining the design.

I bought a circuit board with IC1 and its associated components (in the "box") already soldered. Even so, as my first project with a lot of SMD components, I approached it with more than a little trepidation. I have not included the digital audio components (IC7, IC2 etc) in my project.

It works perfectly via the speakers. The tactile screen is OK, and so is the (Jaycar) remote control. But there is a loud background noise when listening through headphones. Apart from that, I am more than happy with the set.

I also notice a very loud humming through the loudspeakers when I power the setup, whether the headphones are plugged in or not. The latter stops after the line "Reset and Power up" is printed out on the serial terminal.

The Explore 100 detects the presence of the phone jack, so transistor Q5 must be OK. Other components that are related to the headphone socket, but not the loudspeakers, are IC5a/d, Q1-4 and D1-2. Could the annoying hum come from any of these?

A subsidiary remark relates to the headphone/speaker volume levels. They don't seem to be memorised. I haven't looked at the MMBasic code yet, but maybe the solution to memorising the headphone/speaker volume levels lies there? Thanks in advance. (D. P., Noumea, New Caledonia)

● We published errata on this project in the April & May 2019 issues, which you can view via our website (go to the Articles → Notes & Errata menu and click on 2019). However, we don't think these are related to your problems.

Some constructors have found transistors Q1-Q4 are running too hot, and they have had to change the four 2.2kΩ resistors to the left of these transistors to higher values. It's worth checking the temperature of those transistors, but that is probably not responsible for your headphone noise either. We suspect a bad solder joint on one of the passive components around IC5, or on one or more pins of IC5 itself.

We had a severe audio noise problem in one of our prototypes which turned out to be a bad solder joint on a resistor, specifically, the 2.2kΩ resistor which connects to pin 6 of IC5b. Solder had adhered to the end of the resistor but had not flowed properly onto the pad below. Adding some flux paste and re-heating that joint until it reflowed properly fixed the problem.

It's interesting that your speaker outputs are mostly unaffected. That suggests that the problem is more likely to be in the headphone amplifier stages built around IC5a/d, but it's hard to be sure. Regardless, those are part of the same IC, so you will need to check that area of the board anyway. Also check the passive components to the left of Q1-Q4, as well as D1, D2 and the components near CON5.

You are right that the speaker/headphone volumes are not saved automatically. This needs to be done manually from the Config page. We've done it this way to avoid writing to the flash excessively. The "Save settings" option saves the current volume settings so that they are applied at the next power-up.

Are Currawong voltages too high?

I recently finished building your Currawong Stereo Valve Amp (November 2014 - January 2015; siliconchip.com.au/Series/277). I'm following the testing procedure in the January 2015 issue and have found some voltages which vary from those mentioned.

The expected 12.3V DC at pins 4 & 5 of the 9-pin valve socket is 15.3V and the HT rail measures 360V DC rather than the expected 320V DC. I tested the toroidal transformer (single unit as described in the October 2016 issue), and it has 237-240V AC at its input, and 131-133V AC plus 2 x 14.2V AC at its outputs. These readings are above the marked voltages of 115V, 12.66V and 2 x 6.3V (in series).

Are these voltages within the acceptable limits? Are the voltages from the toroidal transformer acceptable? (S. S., Labrador, Qld)

● All the voltages readings will be higher when you don't have the valves plugged in. However, we think the new all-in-one transformer also produces higher voltages than the two separate transformers we used in the original prototype. Also, your mains voltage is a little on the high side; it's closer to the nominal 230V AC at our office.

We aren't overly concerned about your voltage readings. We suggest that you plug in the valves in and re-check them. Assuming they come down at least a bit, your amplifier should be OK. Ideally, the 9-pin heater voltages should drop below 13.5V (within 10% of 12.3V). 360V HT is not a problem, but that's likely to drop a bit too when all the valves are plugged in.

Low-cost spectrum analyser wanted

I am after a cost-effective spectrum analyser. I need one that can operate around the 900MHz mark. Your last article on one was 1978. Is this worth a revisit as a DIY kit? (S. T., Crystal Brook, SA)

● Silicon Chip's first issue was on November 1987, so perhaps you are thinking of a 1978 *Electronics Australia* article. Regardless, We have reviewed several low-cost spectrum analysers since then, such as the:

1. Signal Hound (October 2014; siliconchip.com.au/Article/8046)
2. Gratten GA4063 (November 2013; siliconchip.com.au/Article/5461)
3. Triarchy USB Mini Spectrum Analyser (February 2014; siliconchip.com.au/Article/6129)
4. Soundlabs' RF Explorer (May 2013; siliconchip.com.au/Article/3792)

We're testing out a cheap USB spectrum analyser at the moment, but its performance is so poor that we may not even bother publishing a review. We suggest you don't buy the absolute cheapest one you can find, as you may be disappointed in its performance! All of the analysers mentioned above are fine, and mostly, they are not too expensive. SC

MARKET CENTRE

Cash in your surplus gear. Advertise it here in SILICON CHIP

KIT ASSEMBLY & REPAIR

KEITH RIPPON KIT ASSEMBLY & REPAIR:
* Australia & New Zealand;
* Small production runs.
Phone Keith: 0409 662 794
keith.rippon@gmail.com

DAVE THOMPSON (the Serviceman from SILICON CHIP) is available to help you with kit assembly, project troubleshooting, general electronics and custom design work. No job too small. Based in Christchurch, NZ but service available Australia/NZ wide.
Email dave@davethompson.co.nz

VINTAGE RADIO REPAIRS: electrical mechanical fitter with 36 years experience and extensive knowledge of valve and transistor radios. Professional and reliable repairs. All workmanship guaranteed.
$17 inspection fee plus charges for parts and labour as required. Labour fees $38 p/h. Pensioner discounts available on application.
Contact Alan, VK2FALW on 0425 122 415 or email bigalradioshack@gmail.com

FOR SALE

tronixlabs.com.au – Australia's best value for supported hobbyist electronics from your favourite brands – along with kits, components and much more – with flat-rate $8 delivery Australia-wide.

LEDs, BRAND NAME and generic LEDs. Heatsinks, fans, LED drivers, power supplies, LED ribbon, kits, components, hardware, EL wire.
www.ledsales.com.au

PCB PRODUCTION

PCB MANUFACTURE: single to multi-layer. Bare board tested. One-offs to any quantity. 48 hour service. Artwork design. Excellent prices. Check out our specials: www.ldelectronics.com.au

NEED A NEW PCB DESIGNED?
Or need to update an old board? We do PCB layouts from circuits, drawings, photocopies or sample boards. Contact Steve at sgobrien8@gmail.com or phone 0401 157 285. Get a new PCB and keep production going!

WANTED

LOOKING FOR:
a) Set of Dick Smith Electronics catalogues from 1975-1982. Must be in pristine condition. Will pay $100 for the set (inc. postage), only one set needed.
b) Copy of a book once sold by Jaycar entitled "High Power Loud Speaker Enclosure Design & construction"'; catalogue number BC1166. Will pay $50 (inc. postage) to the first with a pristine copy, ie, little use; slight dog ears OK.
Contact Melanie (on behalf of inquirer on 02 8832 3100)

MISCELLANEOUS

ASSORTED BOOKS FOR $5 EACH
Selling assorted books on electronics and other related subjects like audio, video, programming etc. The books are relatively old in most cases and vary in condition. All books can be viewed at:
https://imgur.com/a/gnSWoll
Some of the books may not be for sale, but the vast majority are available. Bulk discount available; post (cost varies) or pickup.
SILICON CHIP
silicon@siliconchip.com.au

ADVERTISING IN MARKET CENTRE

Classified Ad Rates: $32.00 for up to 20 words (punctuation not charged) plus $1.20 for each additional word. Display ads in Market Centre (minimum 2cm deep, maximum 10cm deep): $82.50 per column centimetre per insertion. All prices include GST. Closing date: 5 weeks prior to month of sale. To book, email the text to silicon@siliconchip.com.au and include your name, address & credit card details, or phone Glyn (02) 9939 3295 or 0431 792 293.

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely. Readers are warned that high voltage wiring should be carried out according to the instructions in the articles.

When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine.

Devices or circuits described in SILICON CHIP may be covered by patents. SILICON CHIP disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. SILICON CHIP also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

Advertisers are warned that they are responsible for the content of all advertisements and that they must conform to the Competition & Consumer Act 2010 or as subsequently amended and to any governmental regulations which are applicable.

Coming up in Silicon Chip

How Satellite Navigation (GNSS) Works
Dr David Maddison explains how satellite navigation systems work, including GPS (USA), GLONASS (Russia), Galileo (EU), BeiDou (China), NavIC (India) and QZSS (Japan).

Super-9 Analog Stereo FM Radio
This radio provides mono or stereo FM reception with excellent sound quality. It's quite sensitive and built mostly from discrete components, with a handful of ICs. It's quite easy to build and suitable for beginners, especially those interested in learning how an FM radio receiver works.

Three I/O Expander modules
Running out of microcontroller pins? These low-cost modules make it a breeze to add more functions to your existing micro. In some cases, they won't take up any more pins on your existing micro and can add dozens more, including pins with PWM capability.

Toyota Synergy Hybrid Drive
Toyota produces arguably the best hybrid drive system, able to move a vehicle under petrol or electric power (or both) with outstanding fuel economy. It provides regenerative braking and the ability to charge the battery while moving or stationary. We take a look at how this clever system works.

Universal 6-24V Battery Charge Controller
This Battery Charge Controller turns a 'dumb' battery charger into a smart charger, suitable for use with various 6V, 12V or 24V batteries, including lead-acid, gel-cell, Li-ion and $LiFePO_4$ (lithium-ion phosphate). It has three preset charging profiles and three adjustable profiles with one to three-stage charging.

Note: these features are planned or are in preparation and should appear within the next few issues of Silicon Chip.

The November 2019 issue is due on sale in newsagents by Thursday, October 24th. Expect postal delivery of subscription copies in Australia between October 22nd and November 8th.

Advertising Index

Altronics 87-90
Ampec Technologies 69
Dave Thompson 111
Digi-Key Electronics 3
Emona ..... IBC
Hare & Forbes ..... OBC
Jaycar IFC,53-60
Keith Rippon Kit Assembly 111
LD Electronics 111
LEACH PCB Assembly 9
LEDsales 111
Microchip Technology 5
Mouser Electronics 7
Ocean Controls 6
PCB Designs 111
Premier Batteries 11
Silicon Chip Shop 40-41
Silicon Chip Subscriptions 97
The Loudspeaker Kit.com 8
Tronixlabs 111
Vintage Radio Repairs 111
Wagner Electronics 68

Notes & Errata

Six-decade Resistor Sorter, Circuit Notebook, September 2019: pin 8 of IC1-IC3 must be connected to the anode of LED7, not the cathode, for the circuit to work correctly.
Gamer's Simulation Seat (High-current H-bridge), September 2019: the 74LS08 IC in the H-bridge should be replaced with a 74HC08 as the LS-series chip has an insufficiently high output voltage to drive the IRFZ44N Mosfets properly. Ideally, those Mosfets should also be changed to a logic-level equivalent such as the CSD18534KCS (Silicon Chip Online Shop Cat SC4177) to ensure they switch on fully with a 5V supply.
Voice Modulator for Sound Effects, Circuit Notebook, August 2019: the diodes in the bottom half of both bridges should be reversed in polarity to form 'rings'. Also, the 180kΩ resistor should be changed to 150kΩ.
Vintage Radio (National AKQ), July 2019: in the circuit diagram on page 95, both batteries are shown with the wrong polarity. This has been fixed in the online version of the magazine.
433MHz Data Range Extender, May 2019: the dimensions of the Jaycar LO1242 powdered-iron core are 15 x 8 x 6.5mm, not 25 x 15 x 10mm as mentioned in the article.
High power H-bridge uses discrete Mosfets, Circuit Notebook, November 2017: the same comment about the 74LS08 chip applies as mentioned above for the Gamer's Simulation Seat.
RGB to Component Video Converter, October 2004: the divider resistors at output pins 7 of IC1b and IC2b should be changed to 820Ω (upper) and 270Ω (lower), resulting in a gain of A = 4 to these stages, in order to achieve the required 2(R-Y) and 2(B-Y) signals at these pins. Note that a separate erratum was published for this project in February 2005.

"Rigol Offer Australia's Best Value Test Instruments"

Oscilloscopes

RIGOL DS-1000E Series

- 50MHz & 100MHz, 2 Ch
- 1GS/s Real Time Sampling
- USB Device, USB Host & PictBridge

FROM $379 ex GST

RIGOL DS-1000Z Series

- 50MHz, 70MHz & 100MHz, 4 Ch
- 1GS/s Real Time Sampling
- 24Mpts Standard Memory Depth

FROM $579 ex GST

RIGOL DS-2000E/A Series

- 70MHz, 100MHz & 200MHz, 2 Ch
- 1GS/s & 2GS/s Real Time Sampling
- From 14Mpts Memory Depth

FROM $912 ex GST

Function/Arbitrary Function Generators

RIGOL DG-1022

- 20MHz Maximum Output Frequency
- 2 Output Channels
- USB Device & USB Host

ONLY $539 ex GST

RIGOL DG-1000Z Series

- 25MHz, 30MHz & 60MHz
- 2 Output Channels
- 160 In-Built Waveforms

FROM $517 ex GST

Multimeters

RIGOL DM-3058E

- 5 1/2 Digit
- 9 Functions
- USB & RS232

ONLY $673 ex GST

Power Supplies

RIGOL DP-832

- Triple Output 30V/3A & 5V/3A
- Large 3.5 inch TFT Display
- USB Device, USB Host, LAN & RS232

ONLY $649 ex GST

Spectrum Analysers

RIGOL DSA Series

- 500MHz to 7.5GHz
- RBW settable down to 10 Hz
- Optional Tracking Generator

FROM $999 ex GST

Real-Time Analysers

RIGOL RSA-5000 Series

- 9kHz to 3.2GHz & 6.5GHz
- RBW settable down to 1 Hz
- Optional Tracking Generator

FROM $11,499 ex GST

Buy on-line at www.emona.com.au/rigol

Sydney
Tel 02 9519 3933
Fax 02 9550 1378

Melbourne
Tel 03 9889 0427
Fax 03 9889 0715

Brisbane
Tel 07 3392 7170
Fax 07 3848 9046

Adelaide
Tel 08 8363 5733
Fax 08 83635799

Perth
Tel 08 9361 4200
Fax 08 9361 4300

EMONA

email testinst@emona.com.au

web www.emona.com.au

HARE&FORBES MACHINERYHOUSE

"Setting the standard for Quality & Value"

A family owned Australian business
Established 1930

THE INDUSTRY'S CHOICE!

CNC Machinery | Metal Working | Sheet Metal Fabrication | Wood Working | Workshop & Automotive | Lifting Handling | Cutting Tools | Machine Tool Accessories | Measuring Equipment

HSS Industrial Centre Drill Set

- 5 piece set
- No. 1, 2, 3, 4, 5
- HSS M2 grade
- Industrial quality

$47.30 (D508)

Metric Precision HSS Jobber Drill Set

- 25 piece set
- Precision ground flutes
- HSS M2 bright finish
- Range: 1~13mm
- 0.5mm increments

$99 (D1272)

Imperial Precision HSS Jobber Drill Set

- 29 piece set
- Precision ground flutes
- HSS M2 bright finish
- Range: 1/16 ~ 1/2"
- 1/64" increments

$104.50 (D1282)

Metric Precision HSS Jobber Drill Set

- 51 piece set
- Precision ground flutes
- 1-6mm in 0.1mm increments
- HSS M2 grade

$126.50 (D1285)

HSS Sheet Metal Step Drill Set

- 3 piece set
- For drilling thin material
- HSS M2 grade
- 4-12mm x 1mm steps
- 6-20mm x 2mm steps
- 6-30mm x 2mm steps

$82.50 (D1071)

HSS Countersink Set

- 4 piece set
- HSS M2 grade
- 45° angle
- Ø2 ~ Ø5mm
- Ø5 ~ Ø10mm
- Ø10 ~ Ø15mm
- Ø15 ~ Ø20mm

$71.50 (D1051)

HSS Countersink Set

- 6 piece set
- HSS M2 grade
- 45° angle
- Ø1.5 ~ Ø6.3mm
- Ø6.3 ~ Ø8.3mm
- Ø8.3 ~ Ø10.4mm
- Ø10.4 ~ Ø12.4mm
- Ø12.4 ~ Ø16.5mm
- Ø16.5 ~ Ø20.5mm

$82.50 (D1061)

Metric HSS Combination Tap & Drill Set

- 7 piece set
- Designed for up to 3.2mm sheet metal
- HSS M2 grade
- M3, M4, M5, M6, M8, M10
- Includes hex snap-on drive

$66.55 (T0191)

Digital Caliper

- 150mm / 6"
- Metric, inch & fraction
- 4-way measuring
- Includes battery

$38.50 (M738)

Digital Caliper

- 200mm / 8"
- Metric, inch & fraction
- 4-way measuring
- Includes battery

$59.40 (M739)

EF-5S - Engineers File Set

- 200mm hardened and tempered files
- Second cut: Flat, 1/2 Round, Round, Square, Triangular
- Includes carry case

$42.35 (F100)

Metric HSS Hole Saw Set

- 11 piece set
- M42 Bi-Metal high speed steel
- 19, 22, 25, 32, 35, 38, 44, 51, 57, 64, 76mm
- Includes 3/8" & 1/2" arbor shank & pilot drill

$110 (D102)

RSP-500 Pneumatic Roller Seat

- 380-500 seat height
- Ø300mm padded seat
- 360° swivel wheels
- Moulded tool tray

$49.50 (A360)

TCS-3 Mobile Tool Cabinet Seat

- 3 x drawers with ball bearing slides
- 420 x 235mm padded seat
- 2 x magnetic side trays
- 406mm seat height
- 360° swivel wheels

$110 (A001)

WCH-6D Workshop Series Tool Chest

- 600 x 260 x 340mm
- 6 drawers with protective liner
- Ball bearing slides
- Key lockable drawers & lid

$110 (T690)

WRC-5D - Workshop Series Roller Cabinet

- 616 x 330 x 762mm
- 5 drawers with protective liner
- Ball bearing slides
- Key lockable drawers
- Includes wheels

$231 (T695)

ALL THIS & MORE IN STORE & ONLINE

- CEYLAN
Staff Member

X6 Industrial Bench Grinder

- 150mm wheels
- Fine/coarse grit
- 0.5hp, 240V motor

EXTRA MACHINERY

$137.50 (G158)

X8 Industrial Bench Grinder

- 200mm wheels
- Fine/coarse grit
- 1hp, 240V motor

EXTRA MACHINERY

$220 (G159)

X8-PLUS - Bench Grinder with Linisher & Mitre Table

- Industrial quality
- 200mm medium grade wheel
- 915 x 50mm linisher attachment
- 1hp, 240V motor

$429 ~~$451~~ (G1590)

UNIQUE PROMO CODE

SC1019

ONLINE OR INSTORE!

VIEW AND PURCHASE THESE ITEMS ONLINE AT
www.machineryhouse.com.au/SC1019

BECOME A MACHINERYHOUSE MATE
www.machineryhouse.com.au/signup

$70 FREE DISCOUNT VOUCHERS

SYDNEY
(02) 9890 9111
1/2 Windsor Rd, Northmead

BRISBANE
(07) 3715 2200
625 Boundary Rd, Coopers Plains

MELBOURNE
(03) 9212 4422
4 Abbotts Rd, Dandenong

PERTH
(08) 9373 9999
11 Valentine St, Kewdale

10_SC_250919

Specifications & Prices are subject to change without notification. All prices include GST and valid until 31-10-19